GUARDRAIL INSTALLER TRAINING GUIDE (GRIT)

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GUARDRAIL INSTALLER TRAINING

I. INTRODUCTION

A. NEED FOR BARRIER TRAINING

1. Fatalities per year/ROR fatalities - Annually there are approximately 42,000 fatalities on our nations highways and nearly 12,000 of them occur as a result of run-off-the-road (ROR) accidents.

2. Guardrail fatalities - Approximately 1,200 of the ROR fatalities are caused by guardrail as the first harmful event (see Table 1).

B. CLEAR ZONE (CZ) CONCEPT

Clear zone definition: The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles.

1. "Magic" 30-foot clear zone - Based on experience in the 1960's at the General Motors Proving Grounds using good vehicles, experienced drivers, a familiar route and flat terrain; nearly 20 percent of the vehicles leaving the traveled way (about 60 out of 300) still went beyond 9 m (30') from the edge of road.

2. Generalized **DESIGN** CZ distances - Based on cross-section, design speed, and traffic volume (see Tables 2a and 2b).

3. Principle - **Provide maximum, cost-effective clear zone.** Any non-removable or non-breakaway obstacle within the **"design"** clear zone will be considered for shielding with a barrier system. The designer should strive for consistency along any section of roadway.

C. BARRIER WARRANTS

Since guardrail itself is a hazard, it should be used only as a last resort. Consideration should first be given to alternative measures to try to avoid the need for guardrail.

1. The first priority should be to eliminate the hazardous situation. Many items such as trees, boulders and jagged rock cuts can be removed, thereby eliminating the need for guardrail.

FIXED OBJECT	1995	1996
Tree/Shrub	3198	3114
Culvert/Ditch	1476	1429
Embankment	1269	1235
Guardrail/Longitudinal Barrier	1215	1169
Utility Pole	1135	1091
Curb/Wall	921	942
Other Fixed Objects	600	583
Sign or Light Support	551	605
Bridge/Overpass	459	433
Fence	432	477
Other Pole/Support	359	401
Concrete Barrier	229	220
Building	77	63
Impact Attenuator	35	26
Fire Hydrant	30	42
Traffic Signal Support	29	29
TOTAL	**12015**	**11859**
TOTAL FATALITIES	**41817**	**41907**

TABLE 1. Fatalities by Fixed Object Struck
FARS 1995 and 1996

TABLE 2a. Clear zone distances (in meters from edge of driving lane)

Design Speed	Design ADT	FILL SLOPES 1:6 or flatter	FILL SLOPES 1:5 to 1:4	FILL SLOPES 1:3	CUT SLOPES 1:3	CUT SLOPES 1:4 to 1:5	CUT SLOPES 1:6 or flatter
60 km/h or less	UNDER 750	2.0-3.0	2.0-3.0	**	2.0-3.0	2.0-3.0	2.0-3.0
	750-1500	3.0-3.5	3.5-4.5	**	3.0-3.5	3.0-3.5	3.0-3.5
	1500-6000	3.5-4.5	4.5-5.0	**	3.5-4.5	3.5-4.5	3.5-4.5
	OVER 6000	4.5-5.0	5.0-5.5	**	4.5-5.0	4.5-5.0	4.5-5.0
70-80 km/h	Under 750	3.0-3.5	3.5-4.5	**	2.5-3.0	2.5-3.0	3.0-3.5
	750-1500	4.5-5.0	5.0-6.0	**	3.0-3.5	3.0-4.5	4.5-5.0
	1500-6000	5.0-5.5	6.0-8.0	**	3.5-4.5	4.5-5.0	5.0-5.5
	OVER 6000	6.0-6.5	7.5-8.5	**	4.5-5.0	5.5-6.0	6.0-6.5
90 km/h	UNDER 750	3.5-4.5	4.5-5.5	**	2.5-3.0	3.0-3.5	3.0-3.5
	750-1500	5.0-5.5	6.0-7.5	**	3.0-3.5	4.5-5.0	5.0-5.5
	1500-6000	6.0-6.5	7.5-9.0	**	4.5-5.0	5.0-5.5	6.0-6.5
	OVER 6000	6.5-7.5	8.0-10.0	**	5.0-5.5	6.0-6.5	6.5-7.5
100 km/h	UNDER 750	5.0-6.0	6.0-7.5	**	3.0-3.5	4.5-5.0	4.5-4.9
	750-1500	6.0-8.0	8.0-10.0*	**	3.5-5.0	5.5-6.0	6.0-6.5
	1500-6000	8.5-9.0	10.0-12.0*	**	5.0-6.0	6.5-7.5	8.0-8.5
	OVER 6000	9.0-10.0*	11.0-13.5*	**	6.5-7.5	8.0-9.0	8.5-9.0
110 km/h	UNDER 750	5.5-6.0	6.0-8.0	**	3.0-3.5	4.5-5.0	4.5-4.9
	750-1500	7.5-8.0	8.5-11.0*	**	3.5-5.0	5.5-6.0	6.0-6.5
	1500-6000	8.5-10.0*	10.5-13.0*	**	5.0-6.0	6.5-7.5	8.0-8.5
	OVER 6000	9.0-10.5*	11.5-14.0*	**	6.5-7.5	8.0-9.0	8.5-9.0

*Where a site specific investigation indicates a high probability of continuing accidents, or such occurrences are indicated by accident history, the designer may provide clear zone distances greater than 9 m as indicated. Clear zones may be limited to 9 m for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

**Since recovery is less likely on the unshielded, traversable 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high speed vehicles that encroach beyond the edge of shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right of way availability, environmental concerns, economic factors, safety needs, and accident histories. Also, the distance between the edge of the travel lane and the beginning of the 1:3 slope should influence the recovery area provided at the toe of slope.

TABLE 2b. Clear Zone Distances (In feet from edge of driving lane)

Design Speed	Design ADT	FILL SLOPES			CUT SLOPES		
		6:1 or flatter	5:1 to 4:1	3:1	3:1	4:1 to 5:1	6:1 or flatter
40 MPH or less	Under 750	7-10	7-10	**	7-10	7-10	7-10
	750-1500	10-12	12-14	**	10-12	10-12	10-12
	1500-6000	12-14	14-16	**	12-14	12-14	12-14
	Over 6000	14-16	16-18	**	14-16	14-16	14-16
45-50 MPH	Under 750	10-12	12-14	**	8-10	8-10	10-12
	750-1500	12-14	16-20	**	10-12	12-14	14-16
	1500-6000	16-18	20-26	**	12-14	14-16	16-18
	Over 6000	18-20	24-28	**	14-16	18-20	20-22
55 MPH	Under 750	12-14	14-18	**	8-10	10-12	10-12
	750-1500	16-18	20-24	**	10-12	14-16	16-18
	1500-6000	20-22	24-30	**	14-16	16-18	20-22
	Over 6000	22-24	26-32*	**	16-18	20-22	22-24
60 MPH	Under 750	16-18	20-24	**	10-12	12-14	14-16
	750-1500	20-24	26-32*	**	12-14	16-18	20-22
	1500-6000	26-30	32-40*	**	14-18	18-22	24-26
	Over 6000	30-32*	36-44*	**	20-22	24-26	26-28
65-70 MPH	Under 750	18-20	20-26	**	10-12	14-16	14-16
	750-1500	24-26	28-36*	**	12-16	18-20	20-22
	1500-6000	28-32*	34-42*	**	16-20	22-24	26-28
	Over 6000	30-34*	38-46*	**	22-24	26-30	28-30

* Where a site specific investigation indicates a high probability of continuing accidents, or such occurrences are indicated by accident history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high speed vehicles that encroach beyond the edge of shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right of way availability, environmental concerns, economic factors, safety needs, and accident histories. Also, the distance between the edge of the travel lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of slope.

2. Regrade steep slopes and ditches, and modify drainage structures, to make them traversable, and fill in depressions.

3. Relocate signs and signals supports, utility poles and endwalls, placing them as a minimum outside of the design clear zone and preferably in an area where they cannot be easily struck.

4. New structures should be designed so that headwalls, piers, and abutments are outside of the design clear zone.

5. Make necessary features within the design clear zone of a breakaway or a yielding design.

Typical features that warrant consideration of barrier installation when inside the design clear zone include:

1. Bridge abutments, piers, and parapet ends generally require shielding

2. Fill slopes steeper than 3:1 with a height of 2.3 m (7' 6") or more (see Figure 1a and 1b)

3. Rough rock cuts and boulders are usually an engineering judgement decision

4. Retaining walls, culverts, endwalls and pipe ends are an engineering judgement based on slopes and distance from the road

5. Severe longitudinal and transverse ditches, such as ditches with front slopes steeper than 4:1 and back slopes of 2:1 or steeper, generally warrant guardrail

6. Non-breakaway sign supports, luminaire supports, and high mast lighting poles

7. Trees with a diameter of 100 mm (4") or more at maturity if they can not be removed

8. Traffic signal supports and railroad warning devices in rural areas on high speed roadways; utility poles on a case-by-case basis

9. Permanent bodies of water more than 600 mm (2') deep

10. Innocent bystander warrants such as playgrounds, schools, etc.

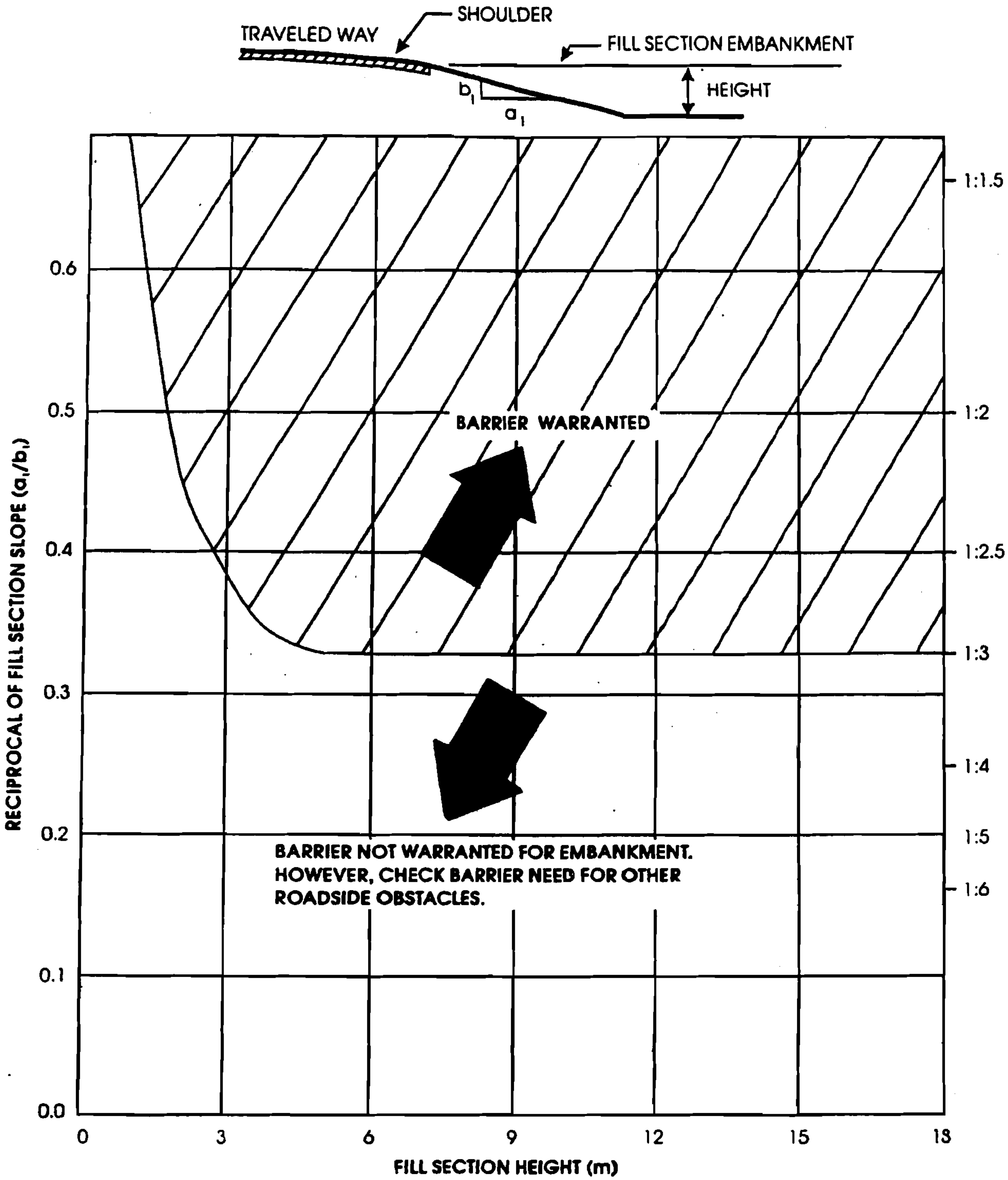


FIGURE 1a. Comparative Risk Warrants for Embankments (Metric)

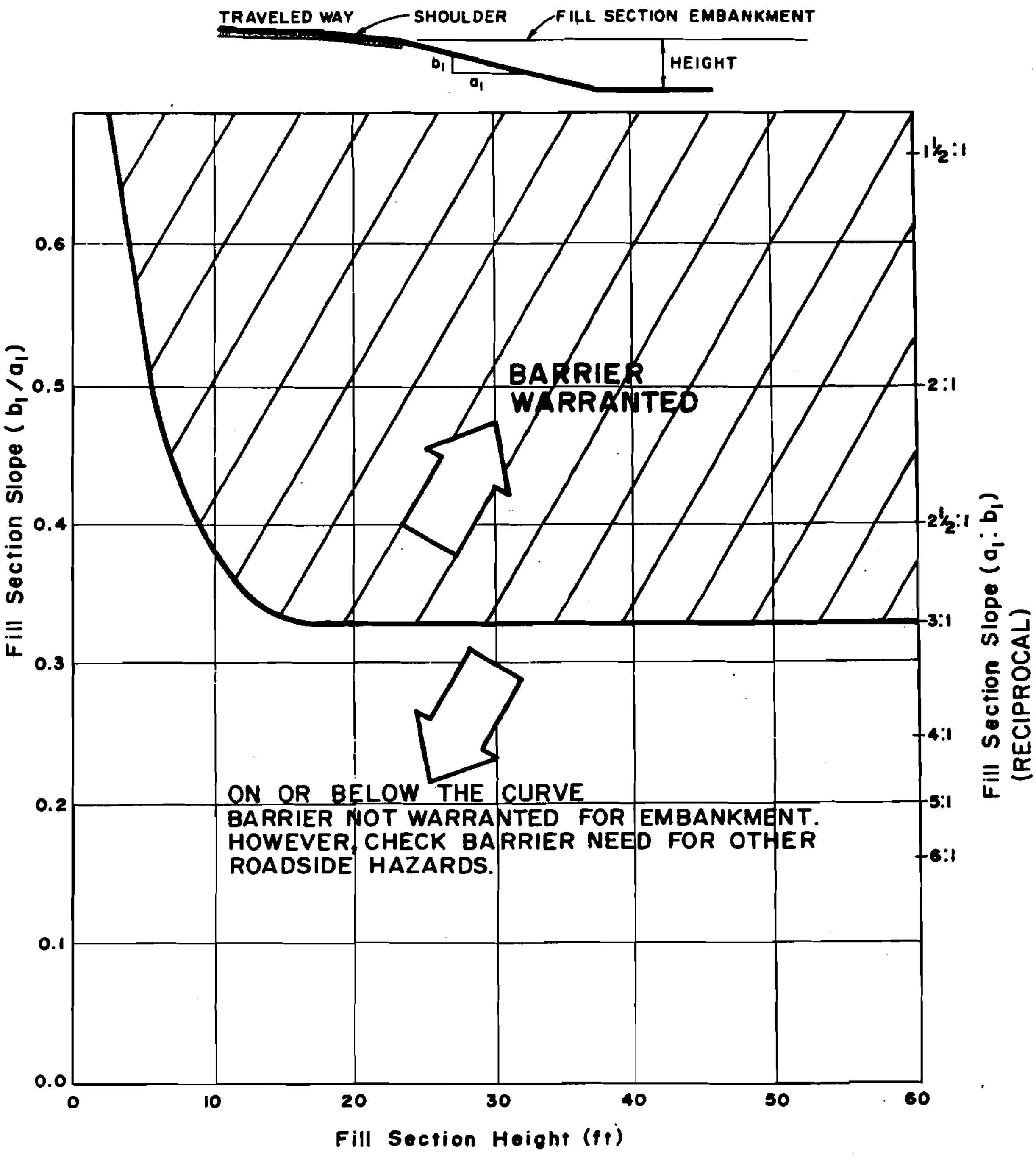


FIGURE 1b. Comparative Risk Warrants for Embankments (English)

II. STANDARD GUARDRAIL SECTIONS

A. NCHRP 350 GUARDRAIL REQUIREMENTS

All new guardrail installations installed by force account or by contract on projects advertised after October 1, 1998 must be with hardware that has passed NCHRP 350 testing criteria. The most common criteria is for Test Level 3 (TL-3) which uses a 2000 kg (4400 lb) pickup truck and a 820 kg (1800 lb) small car impacting at 100 km/h (62 mph). Lower speed test levels and larger vehicle test levels are also available where appropriate. For the standard guardrail sections there are two basic crash tests required: one is a strength test, using the pickup truck at the designated speed impacting at 25°, and the other is the severity test, using the small vehicle at the designated speed striking at 20°. For higher test levels, larger trucks are used, impacting at 80 km/h (48 mph) and at 15°.

B. NCHRP 350 APPROVED GUARDRAIL SYSTEMS

1. Weak Post Cable System

a. Height of cable - The top cable is 685 mm (27") above the groundline. The cables are 75 mm (3") apart.

b. Posts - Steel posts shall be 1.6 m (5' 3") S75 x 8.5 with a 200 mm x 600 mm (8" x 24") soil plate.

c. Post spacing - The standard post spacing is 4.8 m (16').

d. Deflection - Maximum dynamic deflection is 3.3 m (11').

e. Tensioning of cable - The terminals on a cable rail system shall be fitted with turnbuckles and spring compensators to maintain and adjust desired cable tensioning for the expected temperature range. (See specification for proper tensioning requirements.)

2. Weak Post W-beam System

Note: Currently, this system has not passed NCHRP 350 TL-3 for high speed roadways, but has passed TL-2 for 70 km/h (45 mph). It is being retested at Penn State University to see if it can be accepted for use on high speed roadways. (Until testing is completed, a state may decide to continue to use it on high speed roadways.)

a. Height of rail - The top of the W-beam is 760 mm (30") above the groundline.

Special note: If grading is steeper than 10:1 (no steeper than 6:1) and the rail is within 600 mm (2') of the shoulder/frontslope hinge point, the height is measured from the shoulder slope extended (See Figure 2). If the rail is down the slope more than 600 mm (2'), see "barrier on slopes" below and measure from ground directly below the rail.

b. Posts - Steel posts shall be 1.6 m (5' 3") S75 x 8.5 steel post with a 200 mm x 610 mm (8" x 24") soil plate.

c. Post spacing - The standard post spacing is 3.81 m (12' 6").

d. Deflection - Maximum dynamic deflection is about 2.2 m (7').

e. Washers - a 44 mm x 44 mm (1 ¾") square washer with a 3.4 mm (⅛") thickness shall be used at each post.

f. Bolts - M8 8 mm (5/16") hex bolts and nuts are to be used for rail connection to the posts.

g. Lapping:

i. For one-way traffic, all W-beam lapping shall be in the direction of traffic. The upstream panel should overlap the downstream panel including the end sections at bridges and trailing end terminals.

ii. With two-way traffic, the laps on the right side of traffic are to be in the direction of traffic.

3. Strong Post, Blocked-out W-beam System

a. Height of rail - The top of the W-beam is 706 mm (27¾") above the groundline.

Special note: If grading is steeper than 10:1 (no steeper than 6:1) and the rail is within 600 mm (2') of the shoulder/frontslope hinge point, the height is measured from the shoulder slope extended (See Figure 2). If the rail is down the slope more than 600 mm (2') see "barrier on slopes" below and measure from the ground directly below the rail.

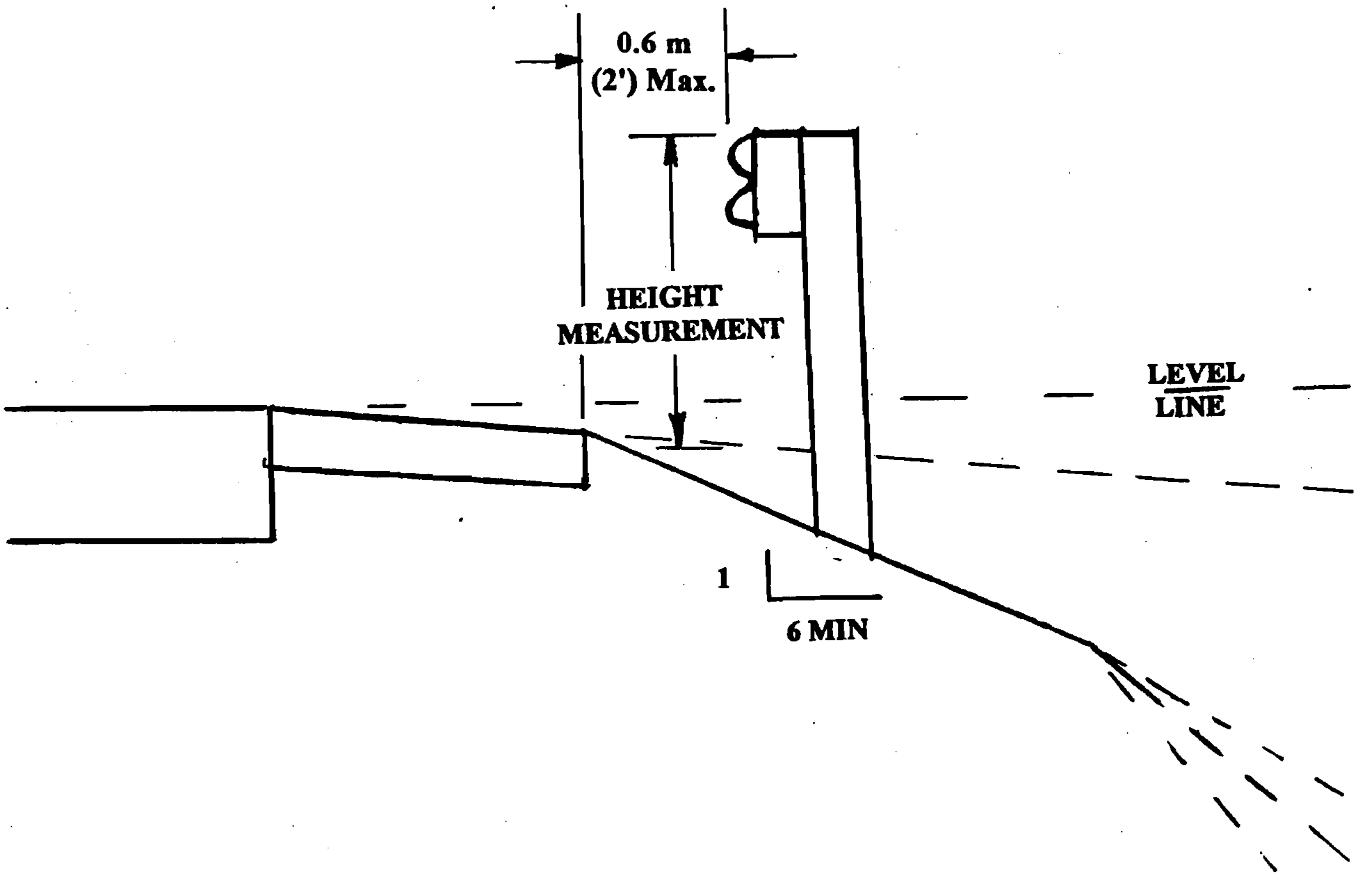


FIGURE 2. GUARDRAIL HEIGHT RELATIVE TO EDGE OF SHOULDER

b. Posts and blockouts:

i. Wood posts - 150 mm x 200 mm x 1830 mm (6" x 8" x 6') with 150 mm x 200 mm x 360 mm (6" x 8" x 14") wood blockouts toe-nailed to posts on the side (near top or bottom) to prevent rotation.

ii. Steel posts - 1830 mm (6') W150 x 12 or 13 with 150 mm x 200 mm x 360 mm (6" x 8" x 14") routed wood or composite blockouts to prevent rotation. (Note: steel blockouts are no longer acceptable for new installations. 150 mm x 150 mm routed blockouts may be used for repair work in special situations.)

c. Post spacing - For either type of post, the spacing is 1.905 m (6' 3").

d. Deflection - Maximum dynamic deflection for both type of posts is approximately .9 m (3').

e. Washers - No rectangular washers shall be used (other than on the last 15 m (50') on trailing runoff ends for anchorage without cables).

f. Lapping:

i. For one-way traffic all W-beam panels shall be lapped in direction of traffic with the upstream panel overlapping the downstream panel including terminal connectors at fixed object attachments and end sections at trailing ends.

ii. For two-way traffic the W-beam guardrail on the right side of traffic shall be lapped in the direction of traffic.

Special note: If an existing steel post, steel blockout system is being retained, there must be a back-up plate (300 mm (12") long piece of W-beam) at each non-splice post and no rectangular washers should be used.

4. Modified Thrie-beam Strong Post System

a. Height of rail - The top of the thrie-beam is 855 mm (33 ½") above the groundline.

b. Posts and blockouts - Same as strong post W-beam steel post system (1830 mm {6'} W150 x 12 or 13) with special 369 mm (14") steel blockouts.

c. Post spacing - The standard post spacing is 1.905 m (6' 3").

d. Deflection - Maximum dynamic deflection is 0.9 m (3') for a 9000 kg (20,000 lb) school bus at 90 km/h (54 mph) impacting at 15°.

5. Weak and Strong Post W-beam Median Barriers

a. Standards - The height of rail, post lengths, blockouts, washer requirements, post spacing and lapping are the same as that for single rail W-beam barrier. For the cable system, the three cables are alternated, the top and bottom cables on the right side and the middle cable on the left side of the posts.

b. Deflection - Maximum dynamic deflection is generally not a concern with median barrier, except that the offset, desirably from the edge of shoulder and absolutely from the edge of traveled way to the face of the barrier, must be greater than the expected deflection.

C. BARRIER LOCATION

The first priority is to place barrier as far from the traveled way as possible to minimize the probability of contact. There are, however, several criteria that must be considered in selecting the location.

1. Deflection

No rigid, vertical object shall be placed within the deflection distance from the back of the barrier system (see Figure 3a). Although **multi-directional** (not bi-directional slip bases) breakaway devices within the deflection distance do not have an adverse effect on the performance of the system, they should be offset wherever possible beyond the deflection distance. This is a PRIMARY ~~major~~ maintenance consideration as well since it should reduce damage to the supports. If dynamic deflection clearance cannot be achieved, the system must be stiffened in front of **and** upstream from the obstacle. Stiffening methods available include decreasing post spacing and double nesting of rail elements. Each stiffening method typically 15 m (50')
halves the defection. The stiffening method should begin 7.~~6 m (25')~~ in advance of the hazard and continue at least to the end of the hazard (where the hazard is a solid obstacle and would not permit pocketing within the

length of the obstacle, the stiffening may be eliminated beyond 7.6 m (25') downstream from the beginning of the obstacle).

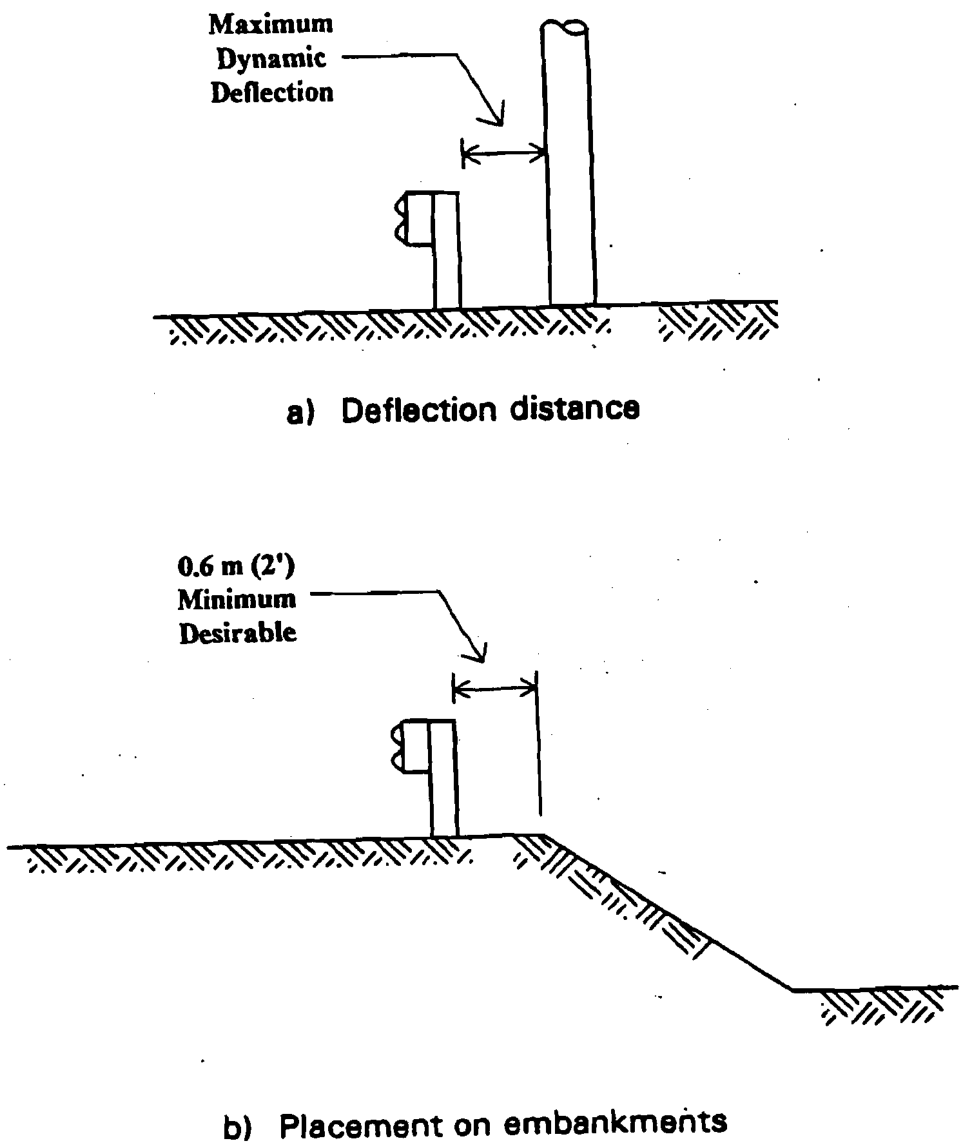


FIGURE 3. RECOMMENDED BARRIER PLACEMENT

FOR OPTIMUM PERFORMANCE

2. Soil Backing

a. Weak Post and Cable systems - The posts' primary purpose is to hold the rail/cable at the proper height. Most of the redirectional capability of the barrier system is developed through the tension in the rail or cable. However, there is still some energy absorbed by the bending of the posts; therefore, some soil backing behind the posts should be provided - the standards show .6 m (2') for new construction.

b. Strong Post systems - Since there is a considerable contribution to the redirection capability of the system from the strength of the strong posts, it is necessary to develop adequate soil support for the post to prevent it from pushing backwards too easily. Desirably, 600 mm (2') of soil behind the post on a slope no steeper than 4:1 should be provided (see Figure 3b). If at least 300 mm (1') of soil support cannot be provided, extra long posts, 2.1 m to 2.4 m (7' to 8'), need to be used in place of the standard length posts.

3. Barriers on Slopes

a. No barrier system is to be placed on slopes steeper than 6:1.

b. A cable system may be placed anywhere on slopes 6:1 or flatter.

c. W-beam systems may be placed anywhere on slopes 10:1 or flatter. On slopes from 6:1 to 10:1, but no steeper, the face of barrier needs to be a minimum of 3.6 m (12') beyond the slope hinge point (see Figure 4).

4. Flare Rate

Flare rate is the rate at which a barrier moves from a larger offset to a closer offset from the edge of traveled way as a vehicle moves downstream. For one-directional roadways, the downstream flare rate, as the barrier moves away from the traveled way, is not restricted. Although it is desirable to flare the barrier system from the traveled way as quickly as possible, there are two criteria that must be satisfied. First, in order to keep the angle of impact with the barrier from being too severe, the flare rate is limited to the values shown in Table 3 which are based on speed and stiffness of the barrier system. Second, barrier should only be flared if it can be done on 10:1 or flatter slopes.

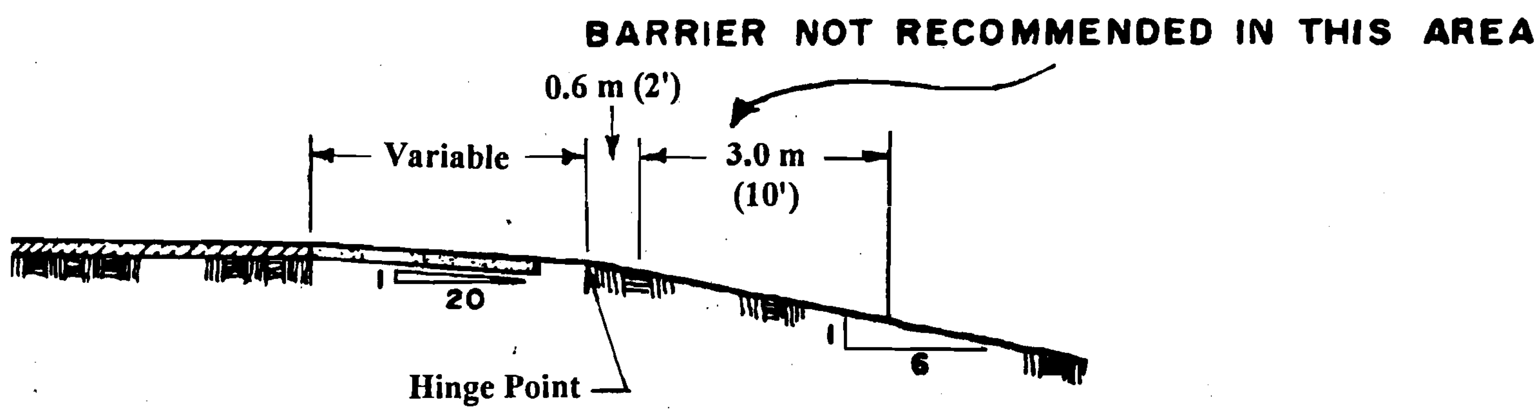


FIGURE 4. RECOMMENDED BARRIER LOCATION ON 6:1 SLOPE

Design Speed km/h(mph)	Flare Rate for Barrier Semi-rigid Systems	Flare Rate for Barrier Rigid Systems
110 (68)	15:1	20:1
100 (62)	14:1	18:1
90 (56)	12:1	16:1
80 (50)	11:1	14:1
70 (43)	10:1	12:1
60 (37)	8:1	10:1
50 (31)	7:1	8:1

TABLE 3. SUGGESTED FLARE RATES FOR SEMI-RIGID BARRIER DESIGN

D. SPECIAL STRONG POST TREATMENTS

1. Left out Post(s)

When it is not possible to drive a full length post due to some obstruction like a drop inlet, shallow culvert or electrical pull box, it is permissible to leave out one or two posts and modify the rail element by adding a second rail section nested inside the normal rail. The nested beams must extend at least to the second post on either side of the gap (see Figure 5). The splice for the back rail must align with the front rail.

2. Extra Blockouts

When a post cannot be driven in its normal location, additional blockouts may be added to provide more offset, allowing the post to be placed farther back. For one post only, and only in unusual circumstances, a total of three blockouts may be used. Two blockouts may be used for special situations for a series of posts. (Note: rail systems using extra blockouts have not been tested.)

3. Special Designs

Some states have special designs for guardrail installations where it is not possible to drive standard posts and the above treatments are not practical. One such design is the use of short steel posts with steel plates welded on the bottom which can be bolted to a concrete slab.

Another common situation is the occurrence of driveways, turnouts, or side roads along what would otherwise be a continuous run of barrier. The most common treatment for this situation is to provide shop-bent W-beam panels around the intersection radius, using either standard post spacing or halving the post spacing to create additional stiffness. Although this treatment should preclude spearing, it is unlikely to provide any redirection and may cause excessive decelerations or vaulting (if the posts lean over). A special design was successfully crash tested at 85 kph (50 mph); the design used weakened wood posts around the radius and removed the bolt from the rail-to-post connection at the center post, and acted somewhat like a bullnose. One caution with this treatment is the need for a sufficient unobstructed area behind the radius to allow for the large deflection of the system - this area should be specified on the detail.

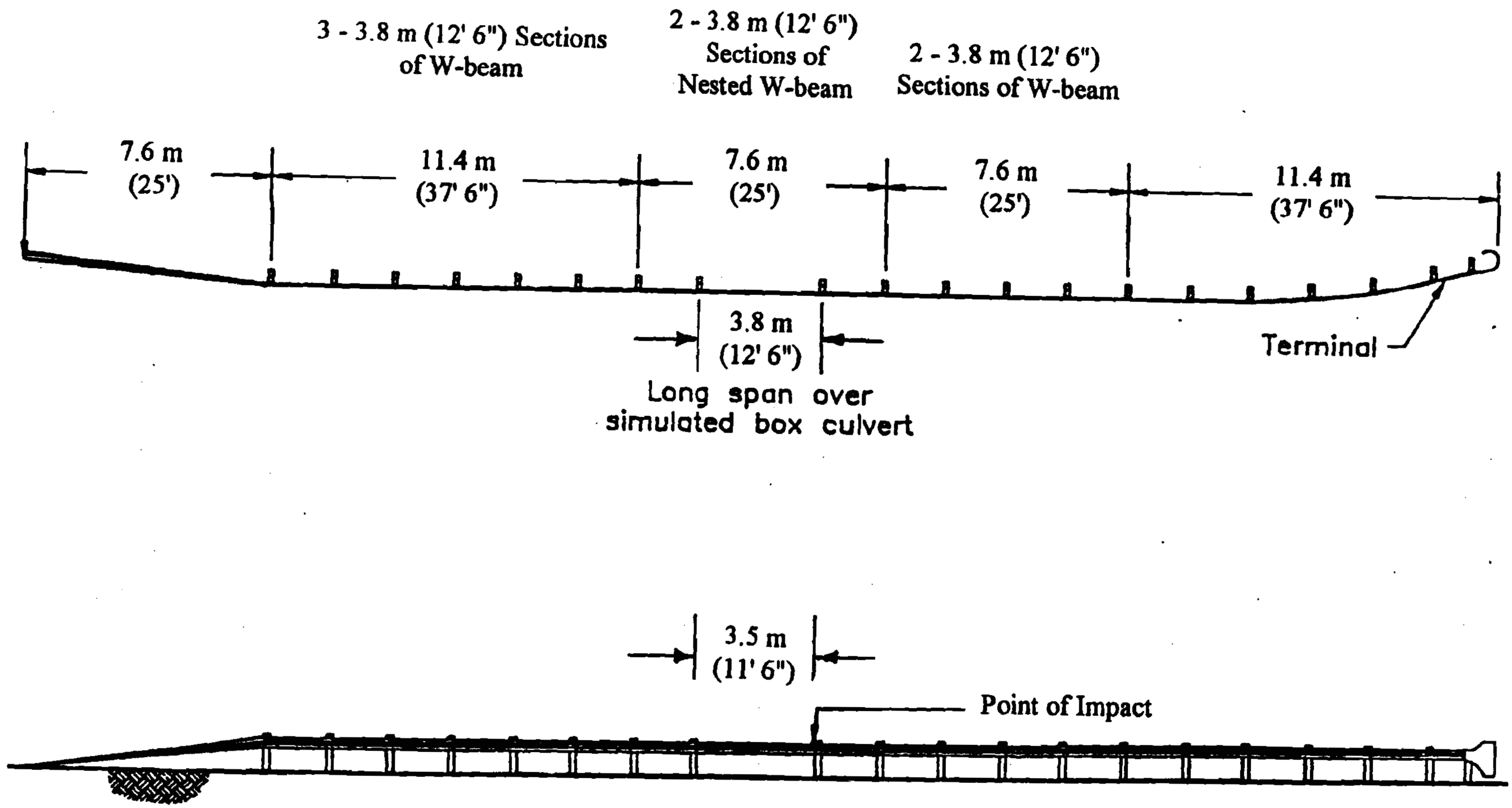


FIGURE 5. NESTING OF W-BEAM RAIL FOR LEFT OUT POST

E. CURB USE WITH W-BEAM BARRIER

Curbs should not be used with barrier installations on high speed, rural roads. If they are, they shall only be used in conjunction with strong post systems subject to the following conditions:

1. Curb height is limited to a maximum of 100 mm (4").

2. For curbs higher than 100 mm (4"), the guardrail system is stiffened by adding another rail, either on the back or nested, or by adding a rubrail underneath the normal rail.

3. Curbs must be flush with the face of the guardrail.

For urban situations, unmodified strong post guardrail can be placed flush with the face of or in front of the curb. The old practice of up to 225 mm (9") behind the face of curb is no longer allowable. If possible, to provide maximum offset, the guardrail should be placed 3.3 m (11') or more behind the curb for high speed (80 km/h {50 mph} or more) roadways and 1.8 m (6') or more behind for low speed (70 km/h {40 mph} or less) roadways. The guardrail height, when placed at a curb, is measured from the roadway surface. When offset from the curb, it is measured from the ground beneath the rail.

F. LENGTH OF NEED DETERMINATION

1. Length of Need (LON) is defined as the length of barrier needed upstream of the beginning of the hazard to shield the hazard.

2. Calculation of the LON is determined from a geometric formula using values based on speed, the distance from the traveled way to the back of the hazard, and the offset of the barrier from the traveled way (see Figure 6).

3. To check whether the LON is satisfactory on high speed roadways, use the field expedient procedure of Figure 7. For low speed roadways, use the value for determining substandard sections for both desirable and minimum LON.

$$X = \frac{L_H + \left(\frac{b}{a}\right)(L_1) - (L_2)}{\left(\frac{b}{a}\right) + \left(\frac{L_H}{L_R}\right)}$$

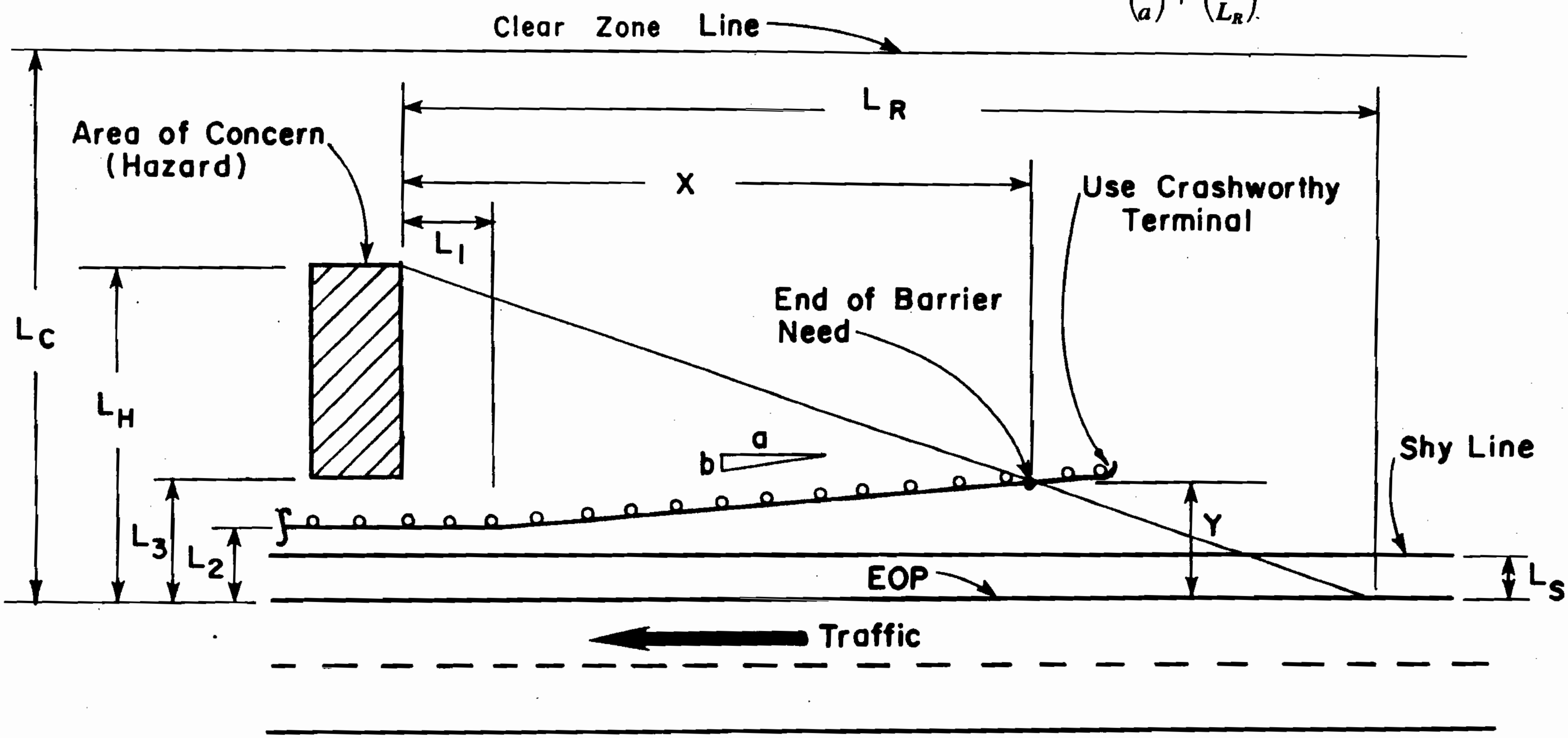
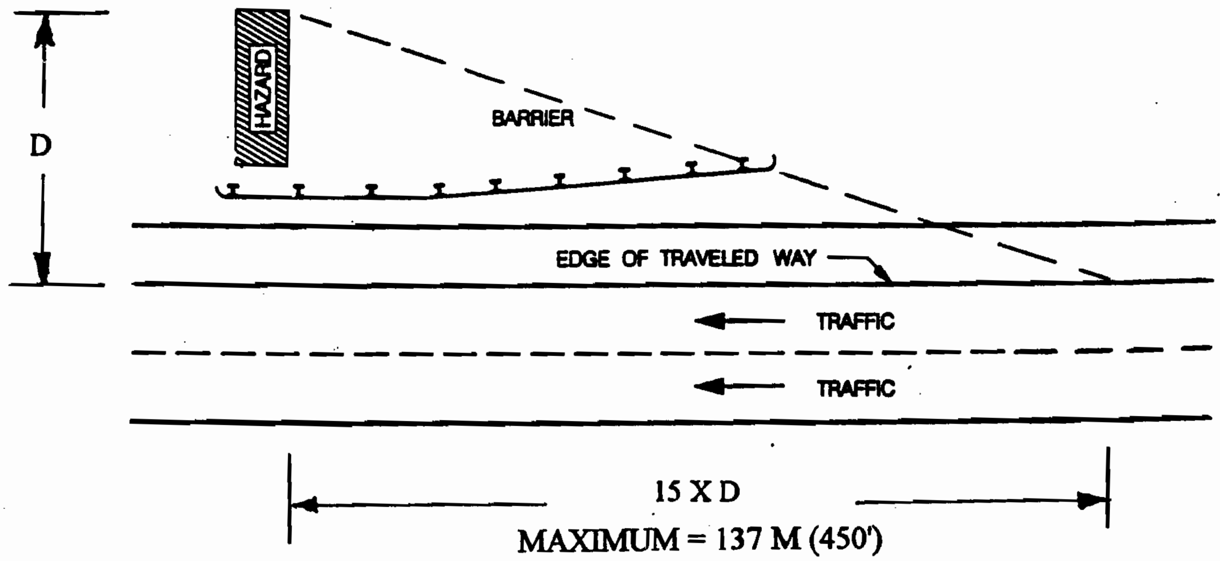


FIGURE 6. APPROACH BARRIER LAYOUT VARIABLES



Procedure:

- Identify upstream face of hazard
- Identify far side back of hazard - limit value to 9 m (30')
- Walk upstream along white edge line, beginning at upstream side of hazard, a distance equal to 15 x D
- Sight from this position to the upstream face, back edge of hazard - limit value to 9 m (30') offset
- End terminal of guardrail run should intercept line of sight

Any existing guardrail run that does not extend across or beyond the line of sight after walking 8 x D upstream from the face of the hazard is significantly substandard.

FIGURE 7. FIELD EXPEDIENT LENGTH OF NEED

III. BARRIER TRANSITIONS

When one barrier system is changed to a stiffer barrier system or connected to a rigid object in the approach direction, a transition must be provided to gradually introduce the stiffer situation. Otherwise, a vehicle may pocket or snag as it comes into the stiffer situation. This applies to all approach traffic - adjacent and from the opposing direction.

A. WEAK POST CABLE TO STRONG POST W-BEAM

The strong post system is to be placed such that it begins 12.7 m (42') back of and upstream of the cable anchorage deadman at an offset distance of 3 m (10') behind the cable rail.

B. WEAK POST W-BEAM TO STRONG POST W-BEAM

Weak post system post spacings must be reduced from 3.81 m (12' 6") to 1.905 m (6' 3") for 7.6 m (25') and then to 0.9525 m (3' 1 ½") for an additional 7.6 m (25'). The height differential should be adjusted in the downstream 3.8 m (12' 6") of the 1.9 m (6' 3") post spacing section.

C. STRONG POST W-BEAM TO RIGID OBJECTS

Rigid objects are defined basically as any unyielding obstacle such as piers, bridge parapet ends, concrete barrier, and retaining walls to which guardrail must be attached. Strong post W-beam (or thrie-beam) is the only system that can be tied into a rigid object. All other systems must be transitioned to the strong post system a minimum of four spaces of 1.905 m (6' 3") prior to beginning a fixed object attachment (a transition). If the blunt end of the rigid object is the only hazard that is being shielded, a TL-3 terminal may be connected directly to the upstream end of the transition.

There are many transition systems available for strong post guardrail to rigid objects. Some are dependent on the shape of the rigid object. The two predominant shapes are a vertical wall and a concrete safety shape. All of these transitions incorporate features to gradually increase the stiffness and provide a smooth, strong connection to the rigid object. First, decreased post spacing; second, double nest two beam sections at the rigid object; third, strong connection to the rigid object; and fourth, a method to prevent wheel snag at the base. Some systems also increase the size of the posts to increase the stiffness.

Transitions to the concrete safety shape are called "direct" transitions and they must have a rubrail or high curb to prevent snagging on the base of the safety shape which protrudes towards the roadway. This includes safety shapes that have the bottom haunch tapered back but do not become vertical. In this case the top rail is blocked out with a spacer tube to be flush with the bottom haunch.

The strong connection to the rigid object is generally made by using a "Michigan shoe" bolted to the concrete. On thinner sections of concrete the bolts should pass completely through the concrete section and have a steel back plate instead of washers under the nuts. Expansion anchors may be used on thicker concrete sections; however, appropriate length bolts should be used. If threaded rods are used, they must not protrude on the traffic side more than 13 mm (½") out from the nut.

IV. GUARDRAIL TERMINALS

The function of a terminal is twofold. It must develop the necessary tension at the end of the system in order to redirect a vehicle and, if hit, minimize the damage to the vehicle and its occupants.

A. NCHRP 350 TERMINAL REQUIREMENTS

All new guardrail terminals installed by force account or by contract advertised after October 1, 1998, must have passed NCHRP 350 testing criteria. There are only three test levels for terminals. They are for speeds of 50, 70 and 100 km/h (30, 42, and 62 mph). Each test level uses a 2000 kg (4400 lb) pickup truck and a 820 kg (1800 lb) small car. To pass the criteria, a terminal may have to pass up to seven individual tests including head on hits and high angle impacts (see Figure 8).

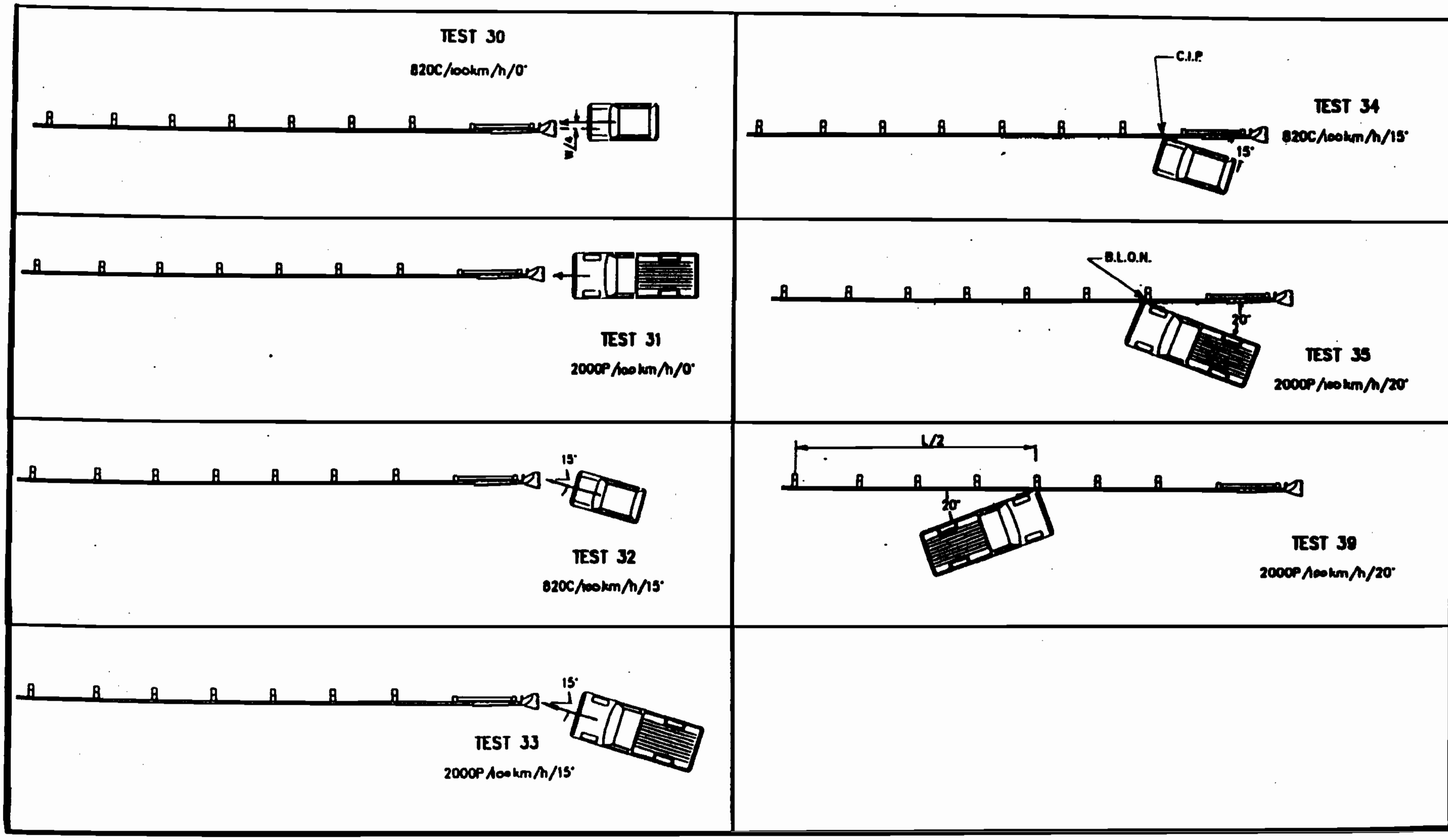


FIGURE 8. IMPACT CONDITIONS FOR TERMINAL AND REDIRECTIVE CRASH CUSHION TESTS

B. NCHRP 350 APPROVED GUARDRAIL TERMINALS

1. Weak Post Cable System

A cable terminal, similar to those in use today, has just recently been tested and probably has passed the testing at TL-3. Until it is formally approved and adopted into the standards, the current standard will continue to be used. This standard shows the cables tapered down to the ground and anchored in a concrete deadman, preferably into a back slope. The location of the terminal should be determined by the LON procedure previously described. If the anchor is buried in the back slope, the full height of the barrier should be carried 22 m (75') upstream of the hazard before flaring beyond the ditchline and tieing into the concrete deadman (see discussion under 3.a below). Constant tension is maintained in the cable system with springs as part of one anchor and turnbuckles to adjust the tension based on the ambient temperature at installation as prescribed in the specifications.

2. Weak Post W-beam System

There is no NCHRP 350 approved terminal for the weak post W-beam system at this time. When the system is installed under TL-2 conditions (low speed), a turn down anchorage which develops the necessary tension may be allowed by the state standard. (This includes an adequate number of bolts to transfer the rail tension to the ground anchor.) When the system is being used in high speed and high volume situations, 15 m (50') of strong post W-beam must be added between the weak post system and the terminal prior to a standard strong post terminal being used. If subject to opposing traffic hits, a transition must also be added between the weak and strong post systems.

3. Strong Post W-beam Systems

a. Buried in Backslope Terminal

The most desirable method to terminate guardrail is to bury the end in a back slope where it cannot be hit end on. This system should also be used even when the barrier system LON would normally end downstream of a cut slope if the cut slope is within 60 m (200') **and** there is not a large available runout area (60 m x 15 m {200' x 50'}) beyond the terminal. The burying must provide the necessary anchorage to develop the tension forces and must be deep enough so that the end of the rail will not become exposed. Two methods of providing the anchorage are available. The first has three 1.8 m (6') steel posts at 0.905 m (3' 1 ½") spacing with steel plates attached (either bolted or welded) to which the beam is attached with four bolts at each post. The second utilizes a concrete deadman 900 x 600 x 600 mm (3 'x 2' x 2') to which the rail is attached with a terminal connector with the bolt anchors either cast or drilled. Each of these anchors must have a minimum of 150 mm (6"), desirably 300 mm (1'), of cover (see standard) which must be compacted on the same plane as the normal ground slope with no mounds or "bubbles" being made. When the front slope between the edge of shoulder and the back slope is 10:1 or flatter, the standard rail system can be flared back to the ditch bottom, then buried and anchored. If there is a ditch at the bottom of the 10:1 slope, the height of the rail should be measured from the 10:1 slope extended and a bottom rail should be added when the height between the groundline and the bottom of the rail exceeds 450 mm (18"). If the front slope is steeper than 10:1, a second rail must be added beneath the top rail and the top of the top rail is held level relative to the edge of shoulder, typically until it reaches the ditch bottom, then is buried and anchored. The bottom rail begins at the first post downstream of where the height between the bottom of the top rail and the ground exceeds ~~425~~ 450 mm (~~17"~~ 18") and is bolted to that post (on the back of the post, at least for two-way roadways). It is then carried across the ditch bottom and buried and anchored to a plate on the last post before the end anchor.

Where a bottom rail is used, the posts are 2.4 m (8') long. No more than 450 mm (18") can be exposed under the bottom rail. No more than this maximum is allowable even if it means lowering the top rail elevation relative to the shoulder edge.

Regardless of whether one or two rails are used, the ~~flare~~ RAIL must not cross the ditch bottom until it has extended a minimum of 22 m (75') for high speed facilities and 15 m (50') for lower speed facilities upstream from the beginning of the hazard being shielded, typically the cut to fill slope transition. This length may be eliminated if the barrier has been extended beyond the normal LON just to bury it and should be noted on the plans. (Two other situations where the length of the rail may be shortened are: (1) if the back slope to which the rail is to be anchored is so steep (1:1 or steeper) as to preclude a vehicle from climbing over the rail; and (2) if the result of a vehicle climbing over the rail (as it is buried) would not present a significant danger.) After it crosses the ditch bottom, it will end 15 m (50') upstream, AND 1' BURRIE offset 2.1-2.4 m (7-8') MAX back from the ditch bottom. This last 15 m (50') may be tapered down to provide the required minimum cover, and the offset may be reduced when a steep backslope would cause the cover to be greater than 300 mm (1').

b. Flared Terminals

A flared terminal configuration is one which flares the end of the terminal from the normal line of the barrier. Currently, only a 1.2 m (4') flare is accepted. (Systems with less than this flare have been successfully tested; the lesser flare may only be used when specially detailed in the plans.) The system is designed to allow a vehicle impacting on/near the end to pass on through the end of the terminal with minimal reduction of speed or energy.

Breakaway Cable Terminals (BCT's) and Modified Eccentric Loader Terminals (MELT's) are types of flared terminals previously used; however, they are no longer acceptable as TL-3 systems under NCHRP 350 requirements.

Types of approved flared terminals include the following:

1. Slotted Rail Terminal (SRT-350)

2. Flared Energy Absorbing Terminal (FLEAT-350)

3. Redirecting Gating End Terminal (REGENT)

All of these terminal systems are proprietary or patented and the manufacturer's installation instructions must be followed. They utilize the breakaway cable anchorage system, described in d. below, to develop the terminal tension. See the manufacturer's literature for specific description and details.

(Note: a non-proprietary terminal, the ELT {Eccentrically Loaded Terminal} has also passed the TL-3 testing; until it is included in the standards it will not be discussed. Also, a slightly modified SRT with a .9 m {3'}offset has passed TL-3 testing and the FLEAT passed TL-3 testing with a 750 mm {2 ½'} offset - these lesser offset systems are essentially the same as described above with the standard offset.)

The offsets for the required flare of the terminal system are to be provided in accordance with the manufacturer's specifications. If the terminal is located on either a tangent or a curve flatter than 900 m (3000') radius, the offsets are measured from a line extended from the standard run of barrier (even if the barrier is on a flare). If the terminal is located on a curve sharper than 900 m (3000'), the offsets for terminals located on the outside of the curve are the same as above. If the terminal is on the inside of the curve, the offsets are measured from a tangential line extended from the end of the standard section of barrier. If the curve is so sharp as to make the offset less than the standard section offset, the offset will be held at the standard section offset.

See Appendixes 6, 7 and 8 for layouts of these proprietary terminals.

As noted above, a vehicle hitting at the end of these terminals, either head-on or at an angle, will break away the end and pass on through with little absorption of energy. Therefore, it is imperative that a large runout area free of hazards be available downstream of the beginning of the terminal; this area would desirably be as long as 75 m (250'), and as wide as 12 m (40') but at least the width of the design clear zone. This amount of area will generally be provided if a Length of Need (LON) determination has been performed. If this large clear area is not available, one of the parallel terminals described below may be more appropriate since for small angle hits they have the capability to capture the vehicle (bringing it to a stop within the terminal length). In all cases, there should be no obstacle less than 22 m (75') from the beginning of the terminal (unless it is connected to a concrete barrier or bridge rail).

c. Parallel Terminals

Parallel terminals are straight systems that may be placed parallel to the roadway. The system is designed to allow a vehicle impacting head on to be brought to a controlled stop by absorbing its energy. For higher angle end impacts, the vehicle will pass through with little absorption of energy and reduction in speed. Some of the parallel systems utilize a large impact head at the beginning of the terminal which could protrude in front of the barrier; therefore, it is desirable to offset this head preferably 600 mm (2') but at least a 300 mm (1'), using a straight line flare for 15 m (50').

Types of approved parallel terminals include the following:

1. Extruder Terminal (ET-2000)

2. Sequentially Kinking Terminal (SKT-350)

   Note: A Beam Eating Steel Terminal (BEST) has also passed NCHRP 350 TL-3, but it essentially is being replaced with the SKT-350.

   These parallel end treatments must use **four** steel foundation tubes for the first four posts. The first two tubes form the breakaway cable anchorage system as described in d. below. The third and fourth tubes (as well as any additional foundation tubes) must use soil plates.

3. Crash-cushion Attenuating Terminal (CAT-350)

4. Brakemaster 350

   The anchorage for these two systems is to be in accordance with the manufacturer's specifications.

All of these terminal systems are proprietary (patented) and the manufacturer's installation instructions must be followed. See their literature for specific description and details.

Since the last two terminals have additional capabilities, they can be used as median or two sided end terminals; however, they are usually more costly and thus not competitive with terminals 1 and 2 for roadside barriers (one side rail) though they are totally acceptable. **The other systems (both flared and parallel) must not have a backrail within 15 m (50') of their beginning.** The Brakemaster may have some advantage in rock areas as it only requires two ground holes for its anchorage; the remaining supports are on skids and slide along a firmly compacted surface. All of the parallel systems must be installed on a straight line for their entire length. The Brakemaster and CAT must not be used on the end of roadside barriers (one side rail) if there is any likelihood that there could be an opposite direction hit on the back side, since this would create a possible spearing/snagging condition.

See Appendixes 6, 7, and 8 for layouts of these proprietary terminals.

The first three systems above utilize the breakaway cable anchorage described below. Although the systems, as noted above, are designed to absorb all the energy of the impacting vehicle for head-on and low angle hits, higher angle impacts will probably result with the vehicle passing through with minimal reduction in energy. Therefore, it is again necessary to have a clear runout area available dowstream of the beginning of the terminal. Again, this area will generally be provided if a Length of Need (LON) determination has been performed. However, there are many cases where it will not be practical to have the guardrail end at the desired location. For those situations, the parallel terminals provide some additional capability over the flared terminals since they will probably capture the vehicle for the (more likely) small angle impact. Since the anchorage for the Brakemaster does not breakaway, it may be better able to capture a medium angle impacting vehicle. In all cases, there should be no obstacle less than 22 m (75') from the beginning of the terminal (unless it is connected to a concrete barrier or bridge rail).

d. Breakaway Cable Anchorage

Terminals with exposed ends have many features in common necessary to assure proper performance in the field. The tests on these systems were conducted on flat ground and under precise installation conditions. Grading will be addressed under the next section. All systems utilize an anchored cable to develop the required tension for downstream hits. For end hits, the vertical end of the terminal is broken away, allowing the vehicle to continue downstream. The Brakemaster system is fairly unique and the following does not generally apply; see the manufacturer's instructions.

For the other systems, the exposed end is a wooden post in a steel foundation tube with a hole near the bottom of the wooden post through which the anchor cable passes. This is called a "breakaway cable anchorage". The cable is restrained with a bearing plate on the upstream side of the post and steel tube, and attached to the rail element just in advance of the second post. If the bearing plate must be restained from ratating, some system of nailin g the plate needs to be done: some systems provide for a nail through the bearing plate; for those that don't, nails should bent over the bearing.

The anchorage cable should be taut which means that the cable can not easily be lifted more than 25 mm (1"). When tightening the nut to make the cable taut, the cable must be restrained from twisting; this can be accomplished by clamping the cable with a wrench while the nut is being turned.

In order to spread the tension developed in the cable anchor to more than the first foundation tube, a steel strut is used to connect the first two foundation tubes. The strut can be used as an indication of proper installation with respect to site grading. There should not be more than 50 mm (2") between the ground and the bottom of the strut and preferably it should be flush with the ground.

Most of the proprietary systems were tested with different length steel foundation tubes. It has been determined that for the breakaway cable anchorage tubes (posts 1 and 2), these different lengths are interchangeable; therefore, it is the installer's option to use: a 1.37 m (4' 6") tube with soil plate; a 1.5 m (5') tube with soil plate; a 1.8 m (6') tube without soil plate; or a 1.95 m (6' 6") tube without soil plate. As noted above under "Approved Parallel Terminals", posts 3 and 4 must have the soil plates except for two special situations: (1) encountering rock - see third paragraph below; and (2) where the soil plate would sever utility lines. When soil plates are required they must always be on the downstream side of the soil tube. For the second exception, the installer must demonstrate (normally by exposing the conflict) to the project engineer's satisfaction that the soil plate will cause damage. In this case only, CRT posts (described below) may be used for posts 3 and 4.

For all posts that are part of the systems that do not sit in steel foundation tubes, weakened wood posts are used which are called CRT posts. The weakened posts allow vehicles that have passed through the end posts to not be severely decelerated, yet provide adequate strength for redirection for downstream hits. The weakening is achieved by drilling two 90 mm (3 ½") holes, one ~~450~~ 400 mm (~~18"~~ 16") below ground and the other centered at ground level. These holes are oriented parallel to the roadway centerline.

Whenever a wood blockout is called for on a wooden post, either in a steel foundation tube or a weakened post, the blockout must be toenailed to the post to prevent rotation.

Normally, installation of the steel foundation tubes is into soil. If rock is encountered, one manufacturer provides an alternative procedure which is to drill a 300 mm (12") diameter hole and cut the foundation tube to a minimum length of 515 mm (20½") and omit the soil plate. The tube must be embedded a minimum of 450 mm (18") **into the rock** and 65 mm (2½") of granular material placed at the bottom of the hole for drainage. If the full tube depth is reached before the 450 mm (18") embedment into rock is achieved, the soil plate must be attached. Back fill of the hole must be compacted; the soil removed from the hole may be used. This alternative may be used with any of the proprietary systems unless there is a more restrictive state specification.

4. Median Barrier Terminals

When a barrier is likely to be hit from either side, only the CAT and the Brakemaster terminals as described above may be used for W-beam or concrete barrier termination. If the barrier is unlikely to be hit on the back side (at least 13 m {40'}) away from traffic, single face barrier terminals may be used if called for on the plans. For the cable barrier system, the current standard terminal will be used. When a terminal is likely to be hit often, or is very close to traffic, a higher type terminal/crash cushion is generally required. This course does not address crash cushions. If a crash cushion is used to terminate W-beam barrier, the barrier system must have its tension requirement provided.

5. Terminals for Curbed Sections

There are currently no terminals tested or approved for use in conjunction with curbs. The best advice is:

a. For high speed roadways

i. Drop the curb to about 50 mm (2") height for a sufficient distance, approximately 15 m (50') in advance of the end of the terminal so the vehicle is at the appropriate height when contact is made. For a parallel-type terminal, the 50 mm (2") height should be carried an additional 3.6 m (12") beyond the upstream end of the terminal, and the end of the terminal should be offset 300 mm (1') to keep the impact head behind the face of curb. For a flared-type terminal, the 50 mm (2") height should be carried 11.4 m (37') beyond the upstream end of the terminal.

ii. Taper the rail back from the face of curb on a 25:1 taper for 15 m (50') raising the height an amount equal to the height of curb, and use a crashworthy terminal based on a line of the ~~50:1~~ 25:1 extended.

b. For low speed roadways use a turned-down terminal, either flush with the curb or flared slightly back, with the height relative to the roadway surface.

6. Trailing End Terminals

The trailing end, or downstream end, of a barrier system that is not likely to be hit by opposing traffic only needs to develop the necessary tension of the barrier system; the second function (minimize damage) is not necessary. In these cases, the full capability of the barrier system is carried to the end of the hazard and then an anchorage is developed. This can be done in several ways.

The best way is to use a "trailing end anchorage" which uses the principle of the anchorage cable which is restrained by the steel bearing plate against a wooden post in a steel foundation tube, similar to approach end terminals. Any of the tube lengths described above for the exposed end terminals may be used; if a soil plate is used, it is placed on the upstream side of the tube. This last post is located approximately two spaces beyond the end of the hazard. Due to the large dynamic deflection of the weak post system, this anchorage should not be used to terminate it.

Another method is to continue the barrier system a sufficient length beyond the hazard to develop its full tension capability at the end of the hazard. For strong post systems this is generally accepted as eight post spacings or 15 m (50') beyond the hazard. When this method is used the rail to post connections must include a washer under the bolt head. The disadvantage of this system is that it places an additional 11 m (37') of unnecessary hazard, the guardrail, along the roadway.

Turned-down terminals that develop the necessary tension may also be used. Again, the full capability of the barrier system must be available at the end of the hazard. This system may be desirable for use to terminate a barrier that is considerably outside the clear zone for the opposing traffic where there is still some likelihood of an opposing traffic hit. The weak post turned-down terminal, with full anchorage, is acceptable for the trailing end of the weak post barrier.

7. Bullnose Terminal

The current design of the Bullnose terminal has not passed NCHRP 350 testing, however, it may be appropriate for use in gores or medians where it is unlikely to be hit.

C. SITE GRADING

With the exception the buried in back slope terminal which was tested on a 6:1 frontslope, crash testing is generally done on flat terrain It is, therefore, desirable to reproduce this feature as close as practical for field installations. For barrier terminal installations that occur at the top of front slopes, the following principles should be followed. If the barrier installation is offset far from the edge of the traveled way in accordance with the criteria described under guardrail on slopes above, the terminals may be placed on that cross-slope.

1. Grading in front of the terminal - The ground must be shaped to a 10:1 or flatter cross-slope for the length of the terminal. There are no exceptions.

2. Grading in advance of the terminal - A grading platform should be developed upstream of the end of the terminal so the approaching vehicle will not be unstable when it strikes the end of the terminal. A triangular wedge must be developed from the edge of the normal shoulder grading to the back of the grading at the end of the terminal, providing a 10:1 cross-slope. The taper on this wedge for new construction and reconstruction should be 15:1; for 3R work the taper should be at least 10:1 (see

Figure 9). The slope beyond the 10:1 platform should be gentle so as not to introduce a discontinuity in the parallel side slope.

3. Grading behind the end post - The 10:1 grading in front of the terminal should extend behind the terminal so that a vehicle impacting the end head on will be relatively level. For new construction and reconstruction, the platform should extend 1 m (3' 3") behind the end post. For 3R work, the grading should be as close as possible to new construction but must extend at least 150 mm (6") behind the end post (see Figure 10).

4. Grading behind the terminal downstream of the end post - The grading should be safely traversable for a vehicle passing through the end post. Because the vehicle may be somewhat unstable after impacting the terminal end, this area should be as flat as possible and extend some distance downstream. Desirably, the slope should be no steeper than 4:1 except in restricted 3R situations.

5. Steel foundation tube protrusion - The top of the steel tube is not to protrude more than 100 mm (4") above the ground. This is the same requirement of all breakaway devices and allows a small vehicle to safely pass over the remaining stub of a breakaway device (see Figure 11). If the steel soil plate of a foundation tube is exposed, adequate grading has not been provided. Also, the steel strut, as described under strong post terminals, is a good telltale of adequate site grading.

6. Payment for grading - For new construction and reconstruction, grading to provide the required site preparation will be incidental to general earthwork. For 3R work, a separate pay item will generally be provided for placement **and compaction** of borrow material. The material must be adequately stabilized to prevent erosion.

D. GAPS BETWEEN BARRIER RUNS

When the end of one barrier run terminates within 60 m (200') of the beginning of the next downstream barrier run of the same type of barrier, and there is no obvious reason for the gap, the terminals should generally be eliminated and the runs connected together.

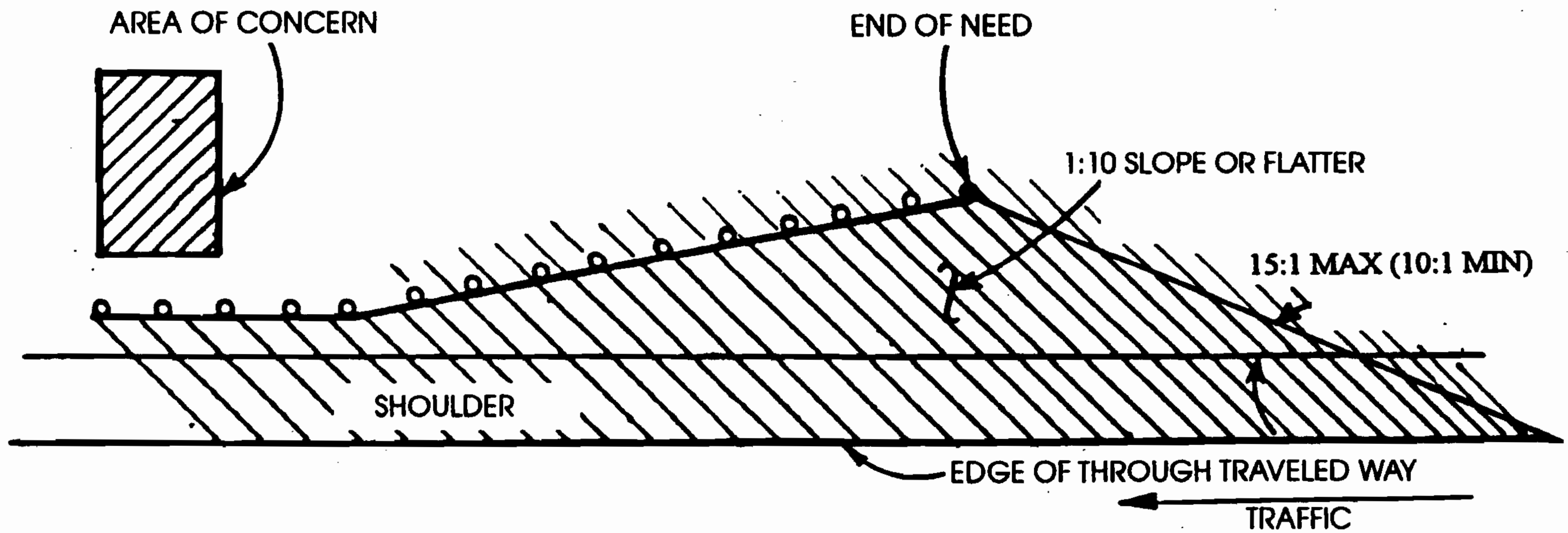
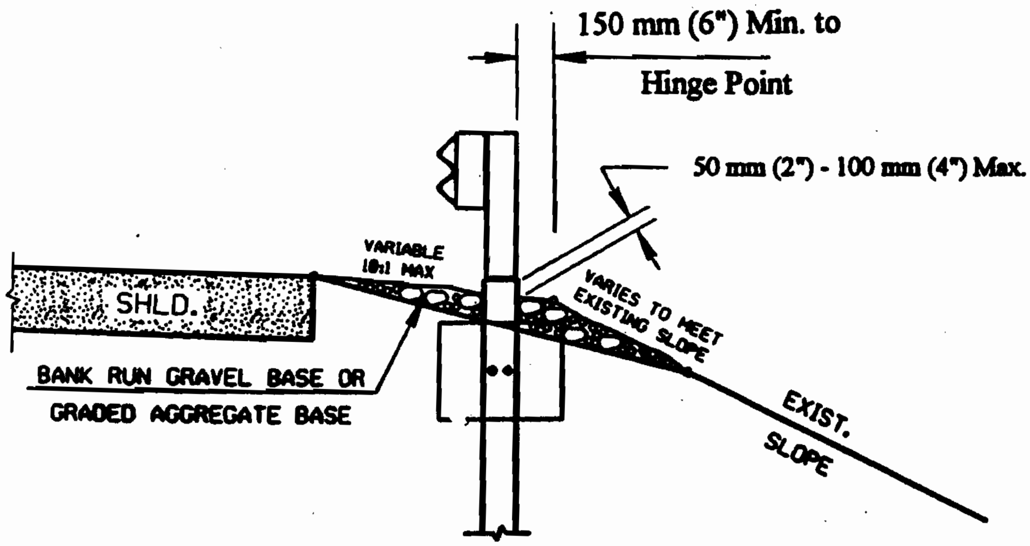
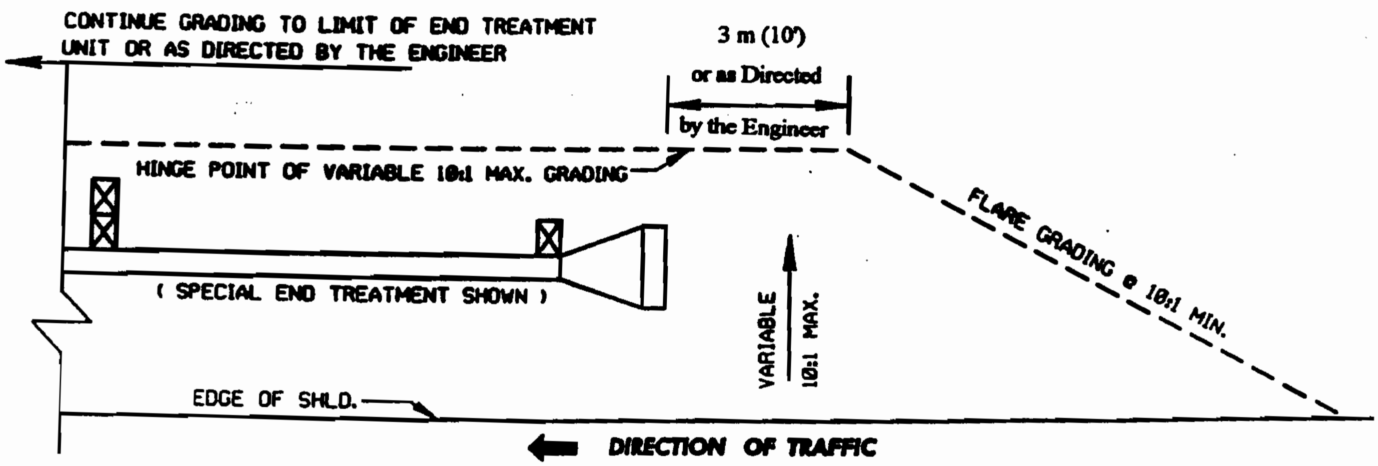


FIGURE 9. SUGGESTED ROADSIDE SLOPES FOR APPROACH BARRIERS



ELEVATION VIEW



PLAN VIEW

FIGURE 10. SPECIAL TRAFFIC BARRIER W-BEAM END TREATMENT GRADING ADJUSTMENT

(Application for 3R Replacement Only for Use with Parallel Terminals)

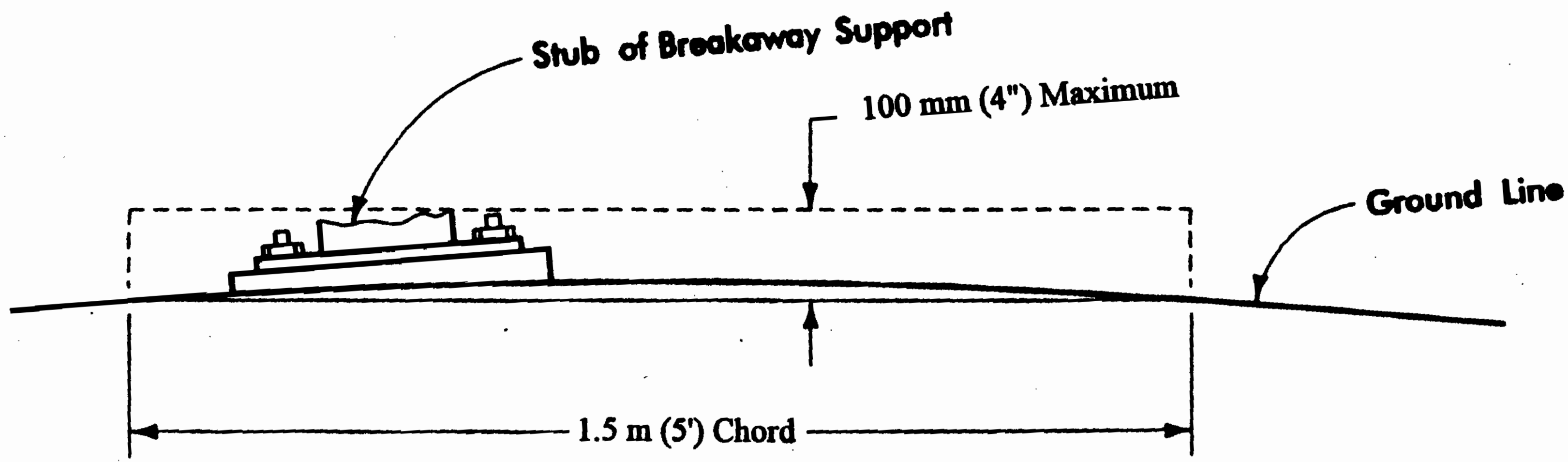


FIGURE 11. BREAKAWAY SUPPORT OR SOIL TUBE STUB HEIGHT MEASUREMENT

V. GENERAL GUARDRAIL SYSTEMS ITEMS

A. BARRIER DELINEATION

Note: All new, repaired, and relocated guardrail and terminals shall have delineation installed.

1. Longitudinal Runs

(The following is a desirable treatment - not all state specifications require this yet. Delineation shall be in accordance with the particular state's specifications and standards.)

a. Delineators shall be made of plastic and be flexible such that when impacted they will return to within 5° of vertical. They shall have a minimum reflective area of 45 sq cm (7 sq in), project no more than 125 mm (5") above the post or blockout, and utilize prismatic lens sheeting.

b. The delineator should be mounted on the web on top of guardrail blockout and if no blockout, on the web on top of the post. If wood blockouts are used, they should be installed on top of the blockout using adhesive, or either stainless or galvanized screws.

c. Install delineators at the spacing specified, typically, a maximum of 24 m (80') on centers. On curves the spacing should be reduced to comply with the spacings specified for interstate road edge delineators. When installed as part of a guardrail repair, at least one delineator should be placed upstream and one downstream of the repair.

d. The color of the delineator should match that of the roadway edgelines.

2. Terminals

(The following is a desirable treatment - not all state specifications require this yet. Delineation shall be in accordance with the particular state's specifications and standards.)

a. Install a minimum 200 mm x 900 mm (8" x 36") yellow encapsulated lens sheeting when a buffered end section is used.

b. When terminals are used that employ an impact head, either solid yellow prismatic lens sheeting, or yellow prismatic lens sheeting with black diagonal stripes should be installed for the full area inside the end of the impact head. When diagonally striped sheeting is used, the black diagonal stripes point down towards the roadway. (Current VDOT standards require diagonally striped sheeting.)

A special situation exists in snow country for terminals that have impact heads that protrude in front of the normal run of guardrail. Experience has shown that many of these terminals are damaged by snowplowing. In order to better mark the inside head of the terminal, a delineator tube which extends well above the top of terminal may be attached directly to the roadside side of the head. Delineator posts should not be placed in front of the terminals.

B. GUARDRAIL IN WORK ZONES

Existing guardrail that is immediately upstream of temporary concrete barrier must be appropriately treated to prevent a vehicle from being directed into the end of the concrete barrier. Two acceptable treatments are to extend the concrete barrier behind and 15 m (50') upstream of the end of the guardrail and flaring the concrete barrier away at a 12½:1 rate; or connect the guardrail to the barrier with a suitable transition and fixed object attachment.

C. NOTED PROBLEMS

1. Standard Sections

a. Too short to provide adequate LON

b. Insufficient deflection offset

c. Rail too low on overlay jobs

d. Rail too high

e. Rotated blockouts due to lack of toe nailing

f. Improper use in conjunction with curbing

g. Improper transitions to stronger sections

h. No offset in front of slope break for strong post soil backing

i. Alignment of rail and plumbness of posts poor

j. Hardware and fasteners left off

k. Fasteners not tight

l. Rectangular washers installed where not required

m. Rectangular washers not installed on trailing standup end of strong post W-beam guardrail

l. Wood blockouts are 150 mm x 150 mm (6" x 6") instead of 150 mm x 200 mm (6" x 8") as required by standard plans

2. Terminals

a. Poor site preparation with steel foundation tubes protruding, strut too high or soil plates exposed

b. Cable not taut

c. Impact heads not parallel to top of rail

d. Exposed ends of W-beam on buried system

e. Improper flare or improper offset on flared terminal

f. End of terminal too high

g. Improper drilled breakaway hole height

h. Two abutting terminals side-by-side in gore and median areas

i. Inadequate length of buried terminal in cut slope

j. Height of buried terminal not consistent across ditchline

k. Buried terminals not graded and seeded properly

l. Terminal located too close to curb

m. No terminal installed on run-off end of weak post W-beam trailing end

3. Terminal Repairs

a. Substandard terminal replaced in kind

4. Fixed Object Attachments

a. Improper post spacing

b. Plates not installed behind parapet walls

c. Use of threaded rods for connection projecting in front of rail

d. FOA's not used at guardrail to temporary barrier locations in work zones

5. Delineation

a. Delineators missing on guardrail runs and terminals

SUMMARY OF DAY ONE

1. DESIGNER'S GUIDING PRINCIPLE FOR ROADSIDE SAFETY
2. STANDARD GUARDRAIL SECTIONS
3. BARRIER LOCATION
4. CURBS WITH GUARDRAIL
5. LENGTH OF NEED - ONE OF THE MOST COMMON DEFICIENCIES
6. TRANSITIONS
7. APPROACH TERMINALS
8. BREAKAWAY CABLE ANCHORAGE
9. MEDIAN BARRIER TERMINALS
10. TRAILING END TERMINALS
11. SITE GRADING - ONE OF THE MOST COMMON DEFICIENCIES
12. GAPS AND DELINEATION
13. "WHAT DO I DO IF I SEE A PROBLEM"

SUMMARY OF DAY ONE

1. Clear Zone

Designer's guiding principle for Roadside Safety - Provide the maximum, economical clear zone possible; no "magic" number; first priority is to remove hazard; and barrier only used if hazard is more severe than impacting barrier; Be consistent!

2. Standard Guardrail Sections

NCHRP 350 specifies tests for acceptable systems - TL-3 uses pickup and small car at 100 km/h (62 mph) up to 25° angle impacts

Tension is the primary contributor to a steel barriers redirection capability; and strong posts provide significant contribution so must develop soil resistance

Barrier height point of measurement - If flat, from directly beneath; if on slope within 600 mm (2') of hinge point, from shoulder slope extended; and if on slope beyond 3.6 m (12'), from directly beneath

Median barriers can be hit from either side; and principles of one sided barrier apply

3. Barrier Location

First priority - Place as far from travel way as possible

Dynamic deflection to a vertical rigid object - Dependent on the barrier system stiffness; multi-directional breakaway devices (signs, luminaires) within deflection distance will not significantly affect performance; and slip base is **not** multidirectional

Barriers place on slopes - Any barrier can be placed anywhere on slope 10:1 or flatter; no barrier on slopes steeper than 6:1; and no W-beam barriers in "No Zone" (0.6 m to 3.6 m {2' to 12'}) for in between slopes

Soil backing - Strong post system uses soil pressure to resist deflection; desirable to have 600 mm (2') backing behind post; and if less than 300 mm (12"), use long post

Flare rate - Although want to get barrier away from traffic as fast as possible, limits on flare rate to control vehicle's redirection and deceleration

4. Curbs with Guardrail

Curbs are not desirable in combination with guardrail; if used, maximum height of 100 mm (4"); if higher, stiffen barrier system; and only strong post system

5. Length of Need (LON) - One of the most common deficiencies

Identify the hazard and its limits - Can it be removed; and does it warrant barrier

Barrier must extend upstream of the beginning of a hazard to intercept a vehicle leaving the travel way at roadway speed; and length is checked in field by sight line procedure

6. Transitions

Barrier systems of lesser stiffness must gradually stiffen to join to stiffer systems downstream

Transitions to rigid objects must provide system tension and prevent snagging; and all accepted transitions use double nested rail elements

7. Approach Terminals

Terminals must provide two functions - Develop the required tension and minimize damage for end impacts

Turndowns are not acceptable except for unusual conditions as permitted by state policy

NCHRP 350 specifies testing - Pickup truck and small car; and up to eight separate tests

Buried in backslope most desirable since cannot spear, farther from the travel way, and generally will not be gotten behind (no LON calculation); use bottom rail if front slope steeper than 10:1; and provide tension anchor

Proprietary flared terminal - Allow vehicle to pass on through for end impacts; and must have adequate runout area behind

Proprietary parallel terminal - Bring low angle impacting vehicles to a controlled stop; higher angled impacts pass on through; and if include an impact head, desirable to have **straight** flare of 600 mm (2'), at least 300 mm (1')

All remaining hardware after posts break away must not exceed 100 mm (4") projection

8. Breakaway Cable Anchorage

Develop the tension for downstream barrier impacts; and post breaks away and releases cable for end on impacts

Uses soil plated or long steel foundation tubes, first two tied together with a strut, to distribute cable tension to soil

Cable must be taut - Cannot lift more than 25 mm (1")

9. Median Barrier Terminals

If terminal likely to be hit from either side, must provide safe redirection on both sides and only two available (CAT and BRAKEMASTER) other than crash cushions

10. Trailing End Terminals

Tension in standard section must be carried beyond the point of need - The end of the hazard for one direction travel; and the LON for two direction roadway

Simplest, least length is the breakaway cable anchorage to develop the tension

Strong post W-beam may use 15 m (50') of additional length, using washers at the post bolts to develop the tension, or a turndown system with deadman anchor

Weak post W-beam may use either the breakaway cable anchorage or a turndown

11. Site Grading - One of the most common deficiencies

The vehicle should be in a stable condition when impacting a terminal - It needs flat ground in front of and behind the upstream end

The breakaway system must not have projection above ground to trip vehicle - Steel foundation tubes must not be higher than 100 mm (4") above ground; the bottom of the steel strut must not be more than 50 mm (2") above ground; and no soil plates visible

12. Gaps and Delineation

Gaps between successive runs of barrier less than 60 m (200') should be filled in

Delineation provides positive guidance to the driver - Apply per state specification to terminal and standard section

13. "What do I do if I see a problem?"

Bring it to the attention of the project engineer; get the District specialist to concur; and document any installation you believe to be **wrong** (not a judgement call)

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LIST OF ACRONYMS

3R	Restoration, Rehabilitation and Resurfacing
AASHTO	American Association of State Highway and Transportation Officials
BCT	Breakaway Cable Terminal
BEST	Beam-Eating Steel Terminal
CAT	Crash Cushion / Attenuating Terminal
CIA	Critical Impact Angle
CIP	Critical Impact Point
CRT	Controlled Releasing Terminal
CZ	Clear Zone
ET	Extruder Terminal
FHWA	Federal Highway Administration
FOA	Fixed Object Attachment
FLEAT	Flared Energy Absorbing Terminal
ISRT	Improved Slotted Rail Terminal (the ROSS)
LON	Length of Need
MELT	Modified Eccentric Loader Terminal
NCHRP	National Cooperative Highway Research Program
REGENT	Redirecting Gating End Terminal
ROR	Run Off the Road
SKT	Sequentially Kinking Terminal

SRT	Slotted Rail Terminal
TL	Test Level (per NCHRP Report 350)

GLOSSARY

Area of Concern: An object or roadside condition that may warrant safety treatment.

Attenuator: A device that lessens, weakens or reduces the severity of an impact.

Barricade: A device which provides a visual indicator of a hazardous location or the desired path a motorist should take. It is not to contain or redirect an errant vehicle.

Barrier: A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect an errant vehicle.

- Rigid Barrier - A longitudinal barrier which does not deflect upon impact and dissipates a negligible amount of the vehicle's impact energy.

- Semi-Rigid Barrier - A longitudinal barrier ranging from practically rigid to quite flexible, which will dissipate some of the impact energy through yielding of the rail and post elements and in some cases, the soil.

- Flexible Barrier - A longitudinal barrier that deflects a considerable distance, dissipating much of the energy, and smoothly redirects a vehicle through the tension in the longitudinal element.

Bearing Plate: A plate used on the first post of a breakaway cable anchorage through which the cable passes to provide bearing. (Standardized hardware nomenclature FPB01)

Breakaway: A design feature which allows a device such as a sign, luminaire, or traffic signal support to yield or separate upon impact. The release mechanism may be slip plane, plastic hinges, fracture elements, or a combination of these.

Breakaway Cable Anchorage: A device designed to develop the tension in a W-beam barrier system using a cable attached to the W-beam rail and passing through a hole in a wood post near ground level and anchored with a bearing plate on the upstream side of the wood post. For downstream impacts on the barrier system, the wood post transfers the tension from the cable to the ground resistance; for end on impacts, the wood post breaks away releasing the cable, allowing the vehicle to continue moving without significant decelerations. Soil resistance is developed by steel foundation tube(s) into which the wood post is inserted.

Bridge Pier: Intermediate support structure for a bridge.

Bridge Railing: A longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.

Buffered End Section: The curved end section used on the beginning end of breakaway cable terminal. (Standardized hardware nomenclature RWE04a)

Center of Mass (c.m.): Point within a test vehicle at which its total mass can be assumed to be concentrated.

Clearance: Lateral distance from edge of traveled way to a roadside object or feature.

Clear Run-out Area: The area at the toe of a non-recoverable slope available for safe use by an errant vehicle.

Clear Zone: The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope and/or a clear run-out area. The "minimum design" width is dependent upon the traffic volumes and speeds, and on the roadside geometry. The desired width is the maximum, cost-effective attainable.

Cost-Effective: An item or action taken which is economical in terms of tangible benefits produced by money spent.

Crash Cushion: An impact attenuator device that prevents an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the hazard.

- Non-redirective Crash Cushion - An impact attenuator that does not control an angle impact on its side and allows pocketing or penetration of the system. The vehicle can reach the hazard.

- Redirective Crash Cushion - An impact attenuator that smoothly controls an angle impact on its side without pocketing or penetrating the system. The vehicle does not reach the hazard.

Crash Tests: Vehicular impact tests by which the structural and safety performance of roadside barriers and other highway appurtenances may be determined. Three evaluation criteria are considered, namely (1) structural adequacy, (2) impact severity, and (3) vehicular post-impact trajectory.

Crash Worthy: A device that has met the evaluation criteria when subjected to the applicable crash tests.

Critical Impact Angle (CIA): For a given test and the attendant range of vehicular impact angles, the CIA is the angle within this range judged to have the greatest potential for causing a failure when the test is assessed by the recommended evaluation criteria. For most tests, impact angles can range from 0 up to 25 degrees.

Critical Impact Point (CIP): For a given test, the C.P. is the initial point(s) of vehicular contact along the longitudinal dimension of a feature judged to have the greatest potential for causing a failure when the test is assessed by the recommended evaluation criteria.

CRT Post: A drilled wood guardrail post used in breakaway terminals.

Curb Mass: Mass of test vehicle with standard equipment, maximum capacity of engine fuel, oil and coolant, and, if so equipped, air conditioning and additional optional mass engine. It does not include occupants or cargo.

Deflection Distance: The distance that a guardrail system deflects when crash tested by a 4400-pound pickup truck at an angle of 25° measured from the back of the guardrail post.

Design Speed: The speed selected and used for correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.

Device: Refers to a design or a specific part thereof, such as a breakaway device. Note that the terms "device" and "feature" are often synonymous.

Drainage Features: Roadside items whose primary purpose is to provide adequate roadway drainage such as curbs, culverts, culvert end treatments, ditches, and drop inlets.

Downstream: The leave side of a feature or trailing end relative to traffic. Synonymous with "run-off".

End Section: A short section of metal hardware used to terminal a run of guardrail.

End Treatment: The designed modification of a roadside or median barrier at its end.

Evaluation Criteria: Criteria used to assess the results of a crash test or to assess the inservice performance of a feature.

Experimental Barrier: One that has performed satisfactorily in full-scale crash tests and promises, but not yet demonstrated satisfactory in-service performance.

Feature: Refers to a specific element of a highway. It may be a hardware item and its associated foundation, such as a sign or barrier installation, or it may be a geometric element, such as a side slope or a ditch cross section.

Fixed Object Attachment: The design used to strengthen and attach a run of strong post guardrail to a immovable fixed object.

Flare: the variable offset distance of a barrier to move it farther from the traveled way.

Flared Terminal: A guardrail terminal that is flared away from the roadway.

Flare Rate: The ratio expressing the flare as the relation of the longitudinal length to the offset distance.

Foundation Tube: A metal tube installed in the soil for the installation of a breakaway wood post used in guardrail terminals. (Standardized hardware nomenclature PTE05)

Frangible: A structure readily or easily broken upon impact.

Gating Device (Feature): A device designed to allow penetration of a vehicle when impacted upstream of the beginning of its redirection capability point. Note: there is some distance between the end of a gating device and the beginning of its redirecting capability.

Geometric Feature: A roadside cross section element such as a ditch section, an embankment, a driveway or a median crossover, or a curb.

Glare Screen: A device used to shield a drivers eye from the headlights of an oncoming vehicle.

Gore: The location where one or more lanes of the road diverge away or converge from the previous direction of travel.

Ground Strut: A metal channel section installed flush with ground at the beginning of breakaway terminals between the first two posts.

Hinge Point: The point where the roadside cross-section changes from one cross-slope to another, such as from the shoulder cross-slope to the frontslope.

Impact Angle: For a longitudinal barrier, it is the angle between a tangent to the face of the barrier and a tangent to the vehicle's path at impact. For a crash cushion/terminal, it is the angle between the axis of symmetry of the crash cushion/terminal and a tangent to the vehicle's path at impact.

Impact Attenuator: See Crash Cushion.

Impact Head: The metal unit that is attached to the end of guardrail terminals which moves down the guardrail when hit dissipating energy though various methods.

Impact Point: The initial point on a test article contacted by the impacting test vehicle.

Lapping: The placement of one section of w-beam over the next downstream section so that the connection will not snag a vehicle.

Length of Need (LON): That length of longitudinal barrier required upstream of an area of concern necessary to appropriately shield the area, containing and redirecting an impacting vehicle.

Longitudinal Barrier: A device whose primary functions are to prevent vehicular penetration and to safely redirect an errant vehicle away from a roadside or median hazard. The three types of longitudinal barriers are roadside barriers, median barriers, and bridge rails.

Median: The portion of a divided highway separating the traveled ways for traffic in opposite directions, measured from edge of traveled way to edge of traveled way.

Median Barrier: A longitudinal barrier used to prevent an errant vehicle from crossing the highway median.

Michigan Shoe: Standardized metal hardware transitioning from a W-beam section to a flat section used to connect W-beam rail to a rigid object. (Standardized hardware nomenclature RWE02)

Nesting: The doubling of the rail element to reduce deflection.

Nongating Device: A device with redirectional capabilities along its entire length. Note that the end of a nongating device is essentially the beginning of its redirecting capability.

Non-Recoverable Slope: A slope which is considered traversable but on which the errant vehicle will continue on to the bottom. Embankment slopes steeper than 4:1 but no steeper than 3:1 may be considered traversable but non-recoverable if they are smooth and free of fixed object hazards.

Occupant Impact Velocity: Calculated velocity at which a hypothetical "point mass" occupant impacts the interior surface of the occupant compartment of a vehicle.

Offset: Distance between the traveled way and a roadside barrier or other obstacle.

Operating Speed: The highest speed at which reasonable prudent drivers can be expected to operate vehicles on a section of highway under low traffic densities and good weather. This speed may be higher or lower than posted or legislated speed limits or nominal design speeds where alignment, surface, roadside development, or other features affect vehicle operations.

Operational Barrier: One that has performed satisfactorily in full scale tests and has demonstrated satisfactory in-service performance.

Parallel Terminal: A guardrail terminal that basically is parallel to the roadway with no more than a two-foot offset.

Penetration: Action of a vehicle passing into or through an appurtenance by overcoming its redirective resistance.

Pocketing: Action of a vehicle creating excessive lateral movement of an appurtenance which can result in an abrupt redirection back into the traffic stream.

Recoverable Slope: A slope on which a motorist may, to a greater or lesser extent, retain or regain control of a vehicle. Slopes equal to or flatter than 4:1 are generally considered recoverable.

Recovery Area: Generally synonymous with clear zone.

Ridedown Acceleration: Acceleration by a hypothetical "point mass" occupant subsequent to impact with a hypothetical occupant compartment of a vehicle.

Roadside: That area between the outside shoulder edge and the right-of-way limits.

Roadside Barrier: A longitudinal barrier used to shield roadside obstacles or non-traversable terrain features. It may occasionally be used to protect pedestrians or "bystanders" from vehicle traffic.

Roadway: The portion of a highway, including shoulders, for vehicular use.

Run-off End: The downstream end or trailing end of a system.

Run-on End: The upstream end or beginning end of a system.

Shielding: The introduction of a barrier or crash cushion, between the vehicle and an obstacle or area of concern to reduce the severity of impacts of errant vehicles.

Shy Distance: The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an immediate hazard by the typical driver, to the extent that he will not change his vehicle's placement or speed.

Slip Base: A structural element at or near the bottom of a post or pole which will allow release of the post from its base upon impact while resisting wind loads.

Slope: The relative steepness of the terrain expressed as a ratio or percentage. Slopes may be categorized as positive (backslopes) or negative (foreslopes), and as parallel or cross slopes in relation to the direction of traffic.

Slope Break: The point at which a shoulder slope and fill meet.

Snagging: When a portion of a test vehicle, such as a wheel, engages a vertical element in a redirective device, such as a post, snagging is said to have occurred. The degree of snagging depends on the degree of engagement. Snagging may cause large and unacceptable vehicular decelerations.

Soil Plate: A rectangular steel plate attached to a guardrail post or soil tube to resist horizontal movement in the ground.

Taut: With respect to a cable anchor, no more than 50 mm (1") lift from its free hanging position.

Terminal: A device designed to treat the end of a longitudinal barrier. An upstream terminal may function by (a) decelerating a vehicle to a safe stop within a relatively short distance; (b) permitting controlled penetration of the vehicle behind the device, (c) containing and redirecting the vehicle, or (d) a combination of a. b. and c. A downstream terminal develops the tension required for the barrier system to properly perform.

Test Article (Test Feature): All components of a system, including the foundation as relevant being evaluated in a crash test. Note that the system may be a geometric feature such as a ditch or driveway slope.

Test Inertial Mass: Mass of test vehicle and all items rigidly attached to vehicle's structure, including ballast and instrumentation. Mass of surrogate occupant(s), if used, is not included in test inertial mass.

Test Level (TL): A set of conditions, defined by NCHRP Report 350 in terms of vehicular type and mass, vehicular impact speed, and vehicular impact angle, that quantifies the impact severity of a matrix of tests.

Test Vehicle: A commercially available, production model vehicle or an approved surrogate vehicle used in a crash test to evaluate the impact performance of a test article.

Three R (3R) Projects: Highway construction projects for restoration, rehabilitation or resurfacing.

Traffic Barrier: A device used to prevent a vehicle from striking a more severe obstacle or feature located on the roadside or in the median, or to prevent crossover median accidents. As defined herein, there are four classes of traffic barriers, namely, roadside barriers, median barriers, bridge railings, and crash cushions.

Transition: A section of barrier between two different barriers or, more commonly, where a roadside barrier is connected to a bridge railing or to a rigid object such as a bridge pier; the upstream barrier system is less stiff than the downstream system. The transition should produce a gradual stiffening of the approach rail so vehicular pocketing, snagging, or penetration at the connection can be avoided.

Traveled Way: The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Traversable Slope: A slope on which a vehicle will likely be steered back to the roadway, be able to retained control of, or continue safely to the bottom.

Upstream: The approach side of a feature relative to traffic. Synonymous with "run-on".

Vehicle: A motorized unit for use in transporting passengers or freight, ranging from an 1800-pound automobile to an 80,000-pound tractor-trailer.

Warrants: The criteria by which the need for consideration of a safety treatment or improvement can be determined.

GUARDRAIL INSTALLER TRAINING (GRIT)

FINAL EXAM

Name: ______________________ Date: ______________

1. What principle does a designer use in determining the **clear zone** width along the roadway?

____

2. What is the "dynamic deflection" of the standard weak post **w-beam barrier** system?
   a. Zero
   b. 1.5 m (5')
   c. 2.4 m (7')
   d. 3.3 m (11')

3. How far down from the hinge point can a weak post **cable barrier** be placed on a 4:1 slope? (Warning - a little tricky)
   a. Zero
   b. 1.8 m (6')
   c. 3.6 m (12')
   d. As far as possible

4. When placed within 2' of the shoulder/frontslope hinge point, what is the normal standard **height** to the top of the **weak post W-beam barrier** and where is it measured from (if the front slope is steeper than 10:1)?
   a. 760 mm (30") above the ground line at the face of the barrier
   b. 760 mm (30") above the edge of the shoulder pavement
   c. 760 mm (30") above the edge of the shoulder slope extended
   d. 706 mm (27¾") above the edge of the shoulder pavement

5. Name two features used to provide improved **transitions** from strong post guardrail **to rigid objects**:

____

6. If a strong post W-beam barrier system goes in front of a rigid object with only 600 mm (2') **deflection** distance available, what is the minimum distance upstream from the beginning of a rigid object that a stiffened transition system needs to begin?
   a. 5.4 m (18')
   b. 7.5 m (25')
   c. 15 m (50')
   d. 22.5 m (75')

7. What is the maximum projection that the remaining portion of a breakaway feature can be above the ground (or 60" chord if not on a straight slope) with proper **site grading**?
    a. 50 mm (2")
    b. 100 mm (4")
    c. 150 mm (6")
    d. Zero

8. For the **strong post W-beam barrier,** the 75x45 mm (3"x 1 3/4") washer is placed under the bolt head connecting the rail to the post and blockout for:
    a. All non-splice post locations
    b. Only when steel blockouts are used
    c. Possibly on the last 15 m (50') of the downstream end of rail (when no crashworthy terminal or cable anchorage trailing end terminal is used)
    d. Only at all the post connections in all the proprietary flared terminals

9. If the back of a hazard is 6 m (20') from the edge line, how far back upstream must one walk along the edge line to check the sight line for good **Length of Need** (LON) of the barrier installation?
    a. 30 m (100')
    b. 60 m (200')
    c. 90 m (300')
    d. 120 m (400')

10. How is the wood blockout on the **strong post W-beam barrier** system prevented from rotating? with wood posts __________ with steel posts ___________

11. If **strong post W-beam barrier** with steel posts is being repaired and the steel blockouts are being left in place, no back-up plates are necessary at the non-splice post locations.
    True ______ False _____

12. What are two indicators of improper **site grading** for terminals that use breakaway cable anchorage systems? ____

____

13. For a **buried in backslope terminal** on a high speed facility, what is the minimum amount of barrier required in advance of upstream face of the hazard to where the barrier crosses the ditch line to be buried in the backslope?
    a. 3.6 m (12½')
    b. 7.5 m (25')
    c. 15 m (50')
    d. 22 m (75')

14. For a **buried in backslope terminal**, how long are the posts when a second, bottom rail is used? _______________ What is the maximum height between the bottom of the lower rail and the ground directly beneath?

a. 150 mm (6")
b. 300 mm (12")
c. 400 mm (16")
d. 450 mm (18")

15. What is the minimum depth under the existing groundline that the end of a **buried in backslope terminal** must be?

a. Flush with the top of rail
b. In accordance with the state standard, but 150 mm (6") minimum
c. 375 mm (15")
d. 600 mm (2')

16. What is the desirable **delineation** to be used for **terminals** that use "impact heads"?

a. 75 mm (3") round delineator buttons
b. Stop signs
c. Diagonal stripe prismatic sheeting
d. Solid yellow encapsulated sheeting

17. What is the definition of "taut" for the cable in **breakaway cable anchorage systems**?

a. The cable lying on the ground for less than 150 mm (6")
b. The cable sagging from a straight line less than 50 mm (2")
c. When pushed down, the cable deflects less than 13 mm (½")
d. When pulled up, the cable is lifted less than 25 mm (1")

18. What is the minimum length of standard strong post W-beam barrier between (1),the upstream beginning of a **transition** to a rigid object, and (2), the downstream end of a run of standard weak post W-beam barrier?

a. None is needed
b. 7.6 m (25'), with a transition from weak post to strong post system in advance of it
c. 15 m (50'), with no transition from weak post to strong post system
d. 15 m (50'), with a transition from weak post to strong post system in advance of it

19. What is the minimum length of standard strong post W-beam barrier between (1), the upstream beginning of a **transition** to a rigid object, and (2), the downstream end of a standard NCHRP 350 TL-3 terminal system?
   a. None is needed
   b. 3.8 m (12' 6")
   c. 7.6 m (25')
   d. 15 m (50')

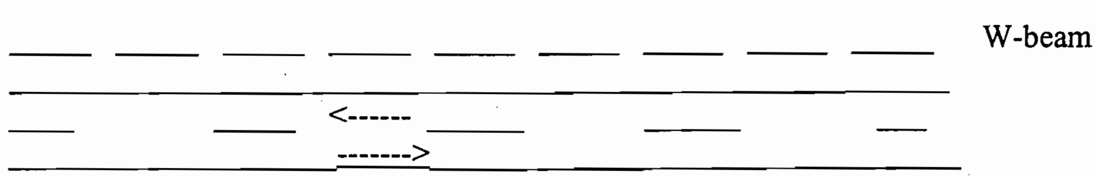
20. What is the recommended method to **transition** a weak post W-beam system to a strong post W-beam system? (As presented in class; current Pennsylvania standard to be/is modified)
   a. 7.6 m (25') of weak posts at 1.9 m (6' 3") spacing followed by 7.6 m (25') of weak posts at .9 m (3' 1 ½") spacing
   b. 15 m (50') of weak posts at 1.9 m (6' 3") spacing
   c. 15 m (50') of weak posts at .9 m (3' 1 ½") spacing
   d. Go straight from weak post system to strong post system

21. Most of the **breakaway cable anchorage system** terminals have some wood blockouts on the wood posts; should these blockouts be nailed to the posts? ______________

22. Many of the **breakaway cable anchorage system** terminals use a "weakened" wood post - the CRT post; how high should the center of the top hole be above the ground and how should it be oriented?
   a. 0 mm (0"), with the hole drilled perpendicular to the direction of traffic
   b. 0 mm (0"), with the hole drilled in line with the direction of traffic
   c. 100 mm (4"), with the hole drilled perpendicular to the direction of traffic
   d. 100 mm (4"), with the hole drilled in line with the direction of traffic

23. What are the two vehicles used for **NCHRP 350 TL-3 testing** of guardrail designs and what are there weights approximately?
   a. A bicycle with a 200 lb rider and a pick-up truck weighing 4400 lb
   b. A small car weighing 1800 lb and a pick-up truck weighing 4400 lb
   c. A small car weighing 1800 lb and a single unit truck weighing 18,000 lb
   d. A motorcycle with a 200 lb rider and a pick-up truck weighing 4400 lb

24. How is the **W-beam** lapped for a two lane, two directional road? Show on the diagram.



25. What is the most common treatment for a strong post W-beam barrier if there is only 6" of **soil backing** behind a post (with a 2:1 slope behind that)?
   a. Switch to a concrete barrier system
   b. Use longer post length {minimum 2.1 m (7')}
   c. Add extra posts to reduce post spacing to 1.8 m (3½ 1/2")
   d. Nest an extra W-beam rail element

26. If you are installing a run of strong post W-beam and a cross culvert pipe is located where a post is to be driven, and the top of the culvert is 2' below the ground line, what is the correct, cost-effective treatment?
   a. Leave the post out
   b. Cut the post off so it won't contact the pipe
   c. Leave the post out, but double nest the rail, extending at least to the second post on each side
   d. Drive the post through the top of the pipe

27. For the **SKT-350 terminal,** what is the typical post spacings?
   a. All spacings are 1905 mm (6' 3")
   b. First two spacings are 1905 mm (6' 3"), the remaining 12 spacings are 952 mm (3' 1 1/2")
   c. First two spacings are 1905 mm (6' 3"), the next 4 spacings are 952 mm (3' 1 1/2"), and the last 3 spacings are 1.27 m (4' 2")
   d. First two spacings are 1905 mm (6' 3"), the remaining 9 spacings are 1.27 m (4' 2")

28. For the **CAT-350 terminal**, what is the typical post spacings?
   a. All spacings are 1905 mm (6' 3")
   b. First two spacings are 1905 mm (6' 3"), the remaining 6 spacings are 952 mm (3' 1 1/2")
   c. First two spacings are 1905 mm (6' 3"), the next 4 spacings are 952 mm (3' 1 1/2"), and the last 3 spacings are 1.27 m (4' 2")
   d. First two spacings are 1905 mm (6' 3"), the remaining 6 spacings are 1.27 m (4' 2")

29. For the **REGENT terminal**, what is the typical post spacings?
   a. All spacings are 1905 mm (6' 3")
   b. First two spacings are 1905 mm (6' 3"), the remaining spacings are 952 mm (3' 1 1/2")
   c. First two spacings are 1905 mm (6' 3"), the next 4 spacings are 952 mm (3' 1 1/2"), and the last 3 spacings are 1.27 m (4' 2")
   d. First two spacings are 1905 mm (6' 3"), the remaining 6 spacings are 1.27 m (4' 2")

30. For all of the terminals, the rail element must be bolted to all posts. True___ False___

31. For a **flared terminal**, which is the most likely final location for a 3500± pound car hitting the end of the terminal at an angle around 8° at 60± mph?

a. Redirected along the front of the rail, stopping 90± m (300±') downstream
b. 3± m (10±') downstream of the original end of the terminal, breaking the first two posts
c. 11.2 m (37' 6") downstream of the original end of the terminal (at the end of the terminal)
d. Probably about 60 m (200') downstream of the original end of the terminal, some distance behind the standard barrier system.

32. For a **SRT-350 terminal**, what is the purpose of the slots? Do the "slot guards" go on the upstream or downstream side of the slot? ____________

a. Reduce the wind load
b. Provide for controlled buckling of rail element
c. Weaken the rail tension so it will rip on impact
d. Provide a location for the slot guard attachment

33. Of the state approved **flared terminals**, what is the standard offset (minimum and maximum are the same) at the upstream end of the terminal?

a. 600 mm (2')
b. 1 m (3' 3")
c. 1.2 m (4')
d. 1.5 m (5')

34. For the **Brakemaster terminal** in an end-on impact, how do the diaphragms move downstream?

____

35. The "parallel type " terminals must only be installed on a straight line in line with the standard run of guardrail? True ___ False ___ Why?

a. They will only work if straight <u>and</u> in line with the downstream barrier
b. It is preferable to have a 300 - 600 mm (1 - 2') straight flared offset to get the impact head away from the line of the barrier
c. It is too difficult to lay out a flare for the terminal
d. It looks ugly if the impact head is in line with the barrier

36. Which two terminals that we discussed should be used if they can be hit from both sides?

a. SRT-350 and REGENT
b. ET-2000 and SKT 350
c. Brakemaster and CAT-350
d. FLEAT and SRT-350

37. The exit openings, for the guardrail to come out after impact, for the ET, SKT, and FLEAT terminals face away from traffic.
True___ False____

38. For the **CAT-350 terminal**, the direction of the lap for the slotted guardrail elements is not critical - translation will occur either way if hit head-on. True ___ False ___

39. For all the **parallel type breakaway cable anchorage terminals**, what length are the first two steel foundation tubes?

a. 1.35 m (4' 6") with soil plate
b. 1.5 m (5') with soil plate
c. 1.8 m or 1.95 m (6' or 6' 6") without soil plate
d. Any of the above

40. For all the **parallel type breakaway cable anchorage terminals**, which of the answer choice(s) from question 39 are allowed for posts 3 and 4? ______________

Exam Answer Sheet

1. MAXIMUM, ECONOMICAL
2. a b c d
3. a b c d
4. a b c d
5. RUBRAILS & CLOSER SPACING OF POSTS
6. a b c d
7. a b c d
8. a b c d
9. a b c d
10. TOE NAILING SIDE EARS ON BLOCK OUT
11. ______ FALSE
12. TOO MUCH STEEL SLOPE STICKING OUT ← STRUT MORE THAN 2' ABOVE GROUND OR NOT ENOUGH AREA BEHIND BARRIER, SOIL PLATES SHOWING
13. a b c d
14. 8' a b c d
15. a b c d – 12" PREFERRED
16. a b c - d
17. a b c d
18. a b c d
19. a b c d
20. a b c d
21. YES
22. a b c d
23. a b c d
24. ______ ______ ______ ______
25. a b c d
26. a b c d
27. a b c d
28. a b c d
29. a b c d
30. FALSE
31. a b c d
32. DOWN STREAM a b c d
33. a b c d
34. SLIDE ALONG THE GROUND
35. F a b c d
36. a b c d
37. F
38 F
39. a b c d
40. A 4'6'

OR B 5'